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BEHAVIORAL INTERDEPENDENCE IN PROJECT TEAM COLLABORATION: STUDY OF ENGINEERING STUDENTS' COLLABORATIVE BEHAVIORS IN HIGH LEVELS OF INTERDEPENDENT TASK SETTINGS

Yiyan Wu
Syracuse University

Abstract

In teamwork learning settings, tasks are often designed at varying levels of interdependence that requires students to complete the tasks by relying only on their team members sharing resources, knowledge, and skills. However, well-structured tasks do not always guarantee task-related collaborative behaviors will occur and are simply not adequate for us to understand the collaboration process and participants' actual collaborative behaviors. To deepen our understanding of collaboration and explore how increased collaboration may be promoted in high-level interdependent task settings, this study uses behavioral interdependence as an analytical concept to describe and examine individual students' actual behaviors as they worked collaboratively on an interdependently-structured engineering design project. Behavioral interdependence is "the amount of task-related interaction actually engaged in by group members in completing their work" (Wageman, 2001, p. 207). The concept of behavioral interdependence helps us to understand students' task-related collaborative behaviors. However, this concept has received scarce attention in collaboration literature.

This study was set in a context of college engineering students collaborating on an authentic design project. A descriptive, instrumental two-case study methodology was employed to respond to two main research questions: (1) what individual behaviors are observed in project teams when students were working under the high task interdependence condition and (2) what patterns of team behaviors are observed in such a condition. After examining and comparing two newly-formed college student project teams' collaborative behaviors in solving an interdependently-structured engineering design project, answers to the research questions help explore how team behavioral patterns formed out of, or were affected by, students' individual behaviors and how behaviors affected team collaboration and performance.

This study resulted in rich descriptions of individual student behaviors and behavior changes, team behaviors and behavior changes, and how individual behaviors were related to team behaviors and overall team collaboration and performance. Results suggested that (1) individual behaviors were closely associated with team behaviors, collaboration, and performance, (2) students' early behavioral patterns largely predicted their continuous behaviors, (3) urgent deadlines were likely to change behaviors of students who had poor performance in task management and temporal planning, (4) individuals performing better in disciplinary, technical areas tended to have more contribution to and better participation in teamwork, and (5) teams with high levels of behavioral interdependence tended to have better performance in teamwork. Several recommendations are provided for designing instruction in high interdependent task settings such as careful estimation of task completion time considering students' varying collaboration skills and time management ability levels (task / activity design recommendation), providing suitable scaffolding strategies to support students who are not adequate in technical fields or in skills in areas of self-management, effective communication, and temporal planning (activity preparation recommendation), and paying attention to students' behaviors at the early stage of their collaboration and providing timely corrective feedback (formative evaluation recommendations).

Key words[1]: collaboration, task interdependence, behavioral interdependence in collaboration process, project team, instrumental case study

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[1] See Appendix U for key concept definitions for this study.

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by

Yiyan Wu

B.A., Jiangxi Normal University, 2000
M.S., Syracuse University, 2005
M.S., Syracuse University, 2013

Dissertation
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Syracuse University
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CHAPTER 1 PROBLEM STATEMENT

Introduction

Collaboration benefits learning in many aspects. Collaboration boosts learners' motivation, challenges them in new tasks that they are interested in but may not be able to do individually, increases their school performance, promotes socialization behaviors, encourages higher-order thinking, and fosters interpersonal skills (Damon, 1984; Chan, 1989; Dillenbourg, Baker, Blaye, & O'Mally, 1996; Jonassen, 2000; Meier, Spada, & Rummel, 2007). However, when collaboration is not carefully structured and implemented, it can result in students' perfunctory performance. Unsuccessful collaborations may lead to unpleasant team behaviors, like member dominance, free-riders (a member of a group obtains benefits from peers without contributing a fair share of work), sucker effects (members' reduction in efforts when they realize someone takes a free-ride) (Salomon & Globerson, 1989), or social loafing (individuals' tendency to spend less effort when working in teams than when working independently) (Karau & Williams, 1993).

Collaboration exists when individual performers participate in and contribute to each other's success of achieving a joint goal (Johnson & Johnson, 2005). When a task cannot be accomplished solely by individuals within a limited time, students often rely on their partners for knowledge, expertise, skills, experiences, time, and other resources that helps lead to a solution. In such a circumstance, (social) interdependence emerges. Interdependence is proposed as the essence of a team and formed among members (Lewin, 1948). Interdependence results in teams becoming a dynamic whole, thus changes in the state or behaviors of one member causes changes in state or behaviors of other members (Johnson & Johnson, 1989, 2005). For this reason, interdependence differentiates teamwork from a collection of individuals.

Therefore, in a collaborative learning situation, tasks are usually *designed to be interdependent* (i.e., structural interdependence) so that they can induce student interdependent, collaborative behaviors (i.e., behavioral interdependence). Interdependence can be structured in areas like project goals, rewards, assignments or tasks, resources, skills, roles, and technology tools. Social interdependence theory suggests that the way in which (social) interdependence is structured determines how individual performers perceive and interact that in turn leads to outcomes (Johnson & Johnson, 1989, 2005). The theory suggests that the way individuals behave in a group is largely determined by each group member's perception of interdependence structured in group task outcomes and means. Specifically, a task is structured interdependently in outcomes and means so individuals perceive that they cannot complete the task if they do not depend on resources, roles, technologies, or skills provided by their partners. When students perceive interdependence *positively* structured in task outcomes and means and realize they cannot complete the joint goal without participation and contribution from each other, they interact "in ways that promote each other's success which, in turn, generally leads to higher productivity and achievement…" (Johnson & Johnson, 1989, p. 5). Such promotive interaction includes a number of behavior variables, including mutual assistance, effective communication, the exchange of needed information and resources, constructive management of conflicts, the advocacy of committed efforts to achieve, trust, and low anxiety about performance. As the theory states, when people take promotive interactions to achieve the joint goal, collaboration exists and continues (Deutsch, 1962, cited in Johnson & Johnson, 2005).

However, the role of individuals' perception of task structure interdependence on their collaborative behaviors was challenged by Wageman (2001). In her research, Wageman showed that student perceptions of tasks covaried with their behaviors and these perceptions did not necessarily come before behaviors. Even when interdependence is structured in outcomes and means of a task, students may not perceive interdependence as positive or necessary at the beginning. As the author suggested, students develop their perception from interpreting and self-observing team members' behaviors rather than examining the task structures themselves at the beginning of collaboration. In addition, what one says or does is affected by and affects the contribution of other members in the team in collaboration (Bonito, 2002). Students' individual behaviors and actions during the collaboration process may encourage other team members' behaviors and further promote team collaboration. By the same token, students' individual behaviors or actions may also discourage their peers and diminish collaboration. Therefore, designed interdependent tasks do not guarantee student collaborative behaviors.

To work successfully in collaboration, especially in tasks that are structured with high levels of interdependence, students are usually required to work with others to complete tasks that they may not have had much experience with while working alone. Such tasks may include planning a teamwork strategy, coordinating individual schedules, breaking tasks down and distributing to each member, and managing team schedules. Students also need to deal with issues that often only arise in team collaboration. This may include explaining ideas to others, listening to others' thoughts and opinions, reaching consensus, coordinating members' efforts and integrating members' contribution together to generate a final solution, and resolving conflicts. Collaborating students "are expected to facilitate others' task performance by providing each other with information, advice, help, and resources" when they are working on tasks (Van Der Vegt, Emans, & Van De VLiet, 1999, p. 202). However, students may lack the skills or awareness to connect with other team members, if they are not used to collaborative settings.

Furthermore, a team's experience in one collaborative context (e.g., playing on a football team) may not be directly applicable to another collaborative project (e.g., work together on an engineering design project without a formal supervisor), especially in newly formed project teams. Project teams are different from working teams, in which members are working together on a daily basis (e.g., football teams, a marketing team). As Janicik and Bartel (2003) described, project teams were usually gathered for tackling complex (short-term) projects, which require expertise and skills from multiple disciplines. In an organization, individuals in project teams usually come from different organizations, divisions, or units. Therefore, people working in project teams are subject to varying temporal constraints like deadlines of a project and other responsibilities from their own units or organizations. Additionally, project teams are usually provided with "minimal formal supervision" therefore have "a high degree of autonomy in deciding how to complete their collective task, correct problems, and improve performance" (Janicik & Bartel, 2003, p. 123) as self-managing teams. Because of these features, students working in project teams may face challenges in (1) managing team structure including task coordination and temporal management, (2) coping with disagreements and conflicted views, and (3) establishing effective communication and information sharing to make quality decisions (Alper, Tjosvold, & Law, 1998).

As a summary, when a task is designed as highly-interdependent collaborative work (i.e., structural interdependence), features embedded in the task do not always elicit student interdependent, collaborative behaviors (i.e., behavioral interdependence) due to the five reasons described above. Evidence is needed to be collected to understand how students actually behave in collaborative task settings and to what extent students' behaviors meet the design expectations. Even when working on the same collaborative task, levels of student behavioral interdependence can vary among different teams. Little research has been done to examine the interdependence differences by looking carefully into students' actual collaborative behaviors. Also, evidence is yet to be found of the collaboration process which may explain the learning or change in work process, social relations, or individual beliefs (Wageman & Gordon, 2005).

In this study, the general research problem examines how to promote increased collaboration in student project teams when students are working on tasks that are structured interdependently. Collaboration is a continuous, collective endeavor. Student behaviors may be the primary observable evidence that can be collected during the collaboration process to evaluate interdependence involved in students' interactions as they collaborate. Therefore, this study was designed to examine individual student behaviors and explore how their behaviors change over time to enhance or diminish collaboration in a high level interdependent task setting (research problem). It is also expected that the data generated from this study can help explore potential factors that may be associated with student behaviors or team interaction patterns when teams are working on high levels of interdependent tasks. Guided by the research problem, the following research questions are addressed.

Research Questions

Research question 1: What individual behaviors are observed in project teams as students work on an interdependently-structured task?

RQ 1-1: How do these behaviors change over time?

RQ 1-2: How may these behaviors affect team performance?

Research question 2: What patterns of team behaviors are observed in project teams as students work on an interdependently-structured task?

RQ 2-1: How do individual students' interactions with each other change over time?

RQ 2-2: How do the team behavior patterns change over time?

RQ 2-3: How may the team behavior patterns affect team performance?

Purpose Statement

The purpose of the study is to describe and examine college students' actual behaviors when collaborating as a newly formed project team on an interdependently-structured engineering design project and to explore how individual and team behavior changes influence team collaboration and may associate with team performance.

The study used an instrumental two-case study methodology employing a descriptive approach. Stake (1995) defined case study as instrumental when selected cases are used to provide insight into an issue or help refine a theory. The case is of secondary interest and plays an analytical and supportive role to facilitate the understanding of something else. The cases selected in this study are two college engineering student project teams, composed of students from two different universities. Teams were newly formed, simply for the purpose of solving an engineering design project in a semester-long course. Such newly formed collaborating teams are similar to project teams described above.

Chapter 1 continues with an introduction to the study context, followed by a brief description of research methodology. A key analytical concept of *behavioral interdependence*, along with major investigated behavior variables, are then introduced. The chapter concludes with a chapter summary, significance statement, and plans for Chapter 2.

Study Context

A Collaborative Engineering Design (CED) course was created and designed by two university professors to engage distributed teams of engineering students in a multiuser, blended synchronous and asynchronous, virtual environment to learn about and solve authentic engineering design problems. This environment, the Advanced Interactive Discovery Environment (AIDE), allowed multiple students entry into this virtual space to participate synchronously in live lectures and discussions to learn about and apply engineering concepts. While inside the AIDE, students were able to share ideas and explore solutions orally and visually through audio and video conferencing (called AIDE SameTime), shared writing and drawing spaces, and data analysis applications. In Figure 1-1, a student was speaking (shown in the screen video: image of student face and students' full names were blocked in this screen capture to protect students' privacy) as he explained his notes on the document shared in Whiteboard. In the meantime, other students were having side-talks in chat.

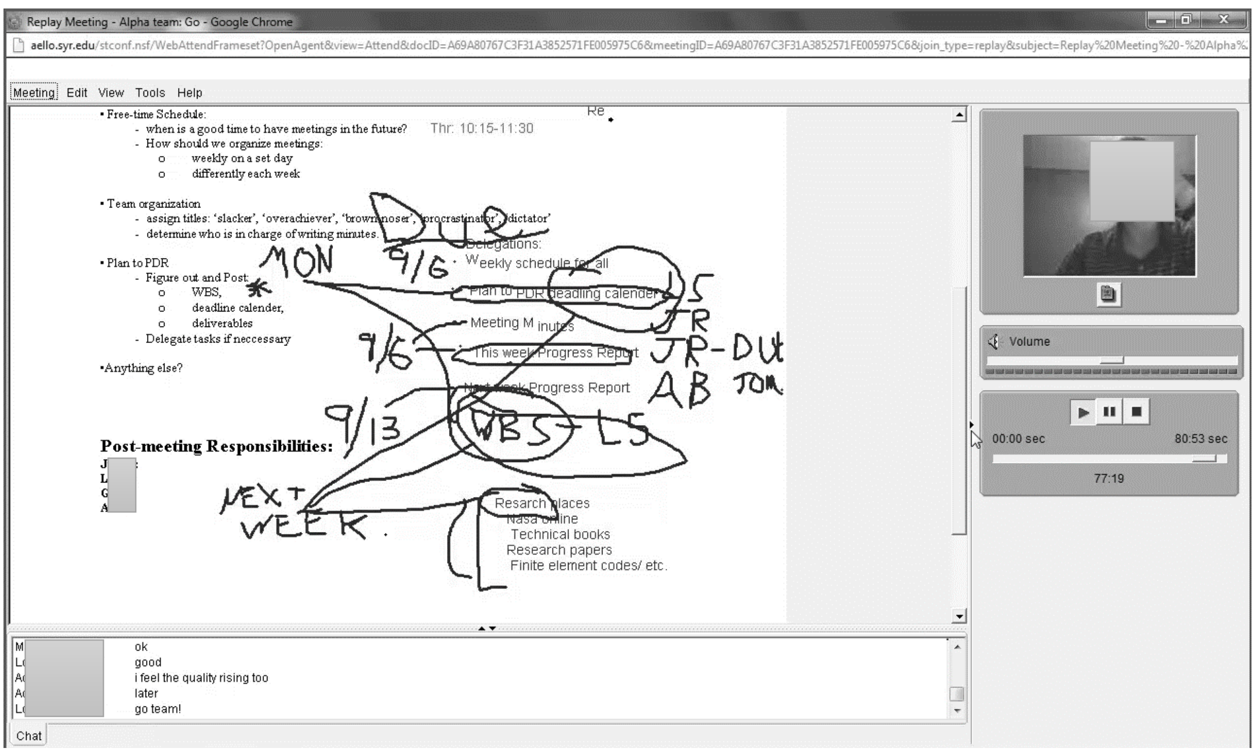

Figure 1-1. A screen capture of AIDE SameTime meeting.

The two instructors from the two universities collaboratively taught this semester-long CED course directly to the students from their home institution and synchronously through the AIDE at a distance for those at the partnering institute. Participating students from both universities simultaneously attended course lectures either in-person at their home institute or through multiuser virtual environment synchronous tools, depending on which of the two professors were responsible for the session content.

At beginning of the class, students were assigned evenly to distributed project design teams with 50% from the local and 50% from the distance university. Participating students were professionally trained at a fundamental level of engineering knowledge in each of their institutions before they were enrolled in the course. As the course started, students received instruction in some foundational engineering content, necessary technology skills, and team-building techniques to be able to participate in the course activities. For several weeks however, the students (in each team) were split into one of two engineering content learning tracks, DSTs (discipline specific tracks: Aerospace Analysis and Finite Element Analysis). Thus students in each team, for the sake of a culminating activity, had different engineering expertise from which to collaborate on a resolution for a given engineering design problem.

The course engineering design problem is a semester-long project that required students to create a preliminary design of a thermo-structural system for a specific location on a hypothetical second-generation Reusable Launch Vehicle (RLV) for NASA (the National Aeronautics and Space Administration) space missions. As described above, each distributed team had a mix of students from both universities and each of the two engineering content tracks. These distributed engineering design teams thus had to bring together different types of engineering knowledge when they were collaboratively solving the design problem. More than that, the task was designed as a highly interdependent design work, in which each member "must take action for other members to do any part of" the work (Wageman, 1995, p. 146). In such a situation, information were distributed among team members. Each member could finish his or her part of the whole work, but only after they completed his or her part and share the work with the team could the whole task be finished (Wageman, 1995).

Four Course Phases

The course was designed in four time phases: (1) Best Practice, (2) Project Planning, (3) Preliminary Design Review (PDR), and (4) Critical Design Review (CDR). The course schedules are attached in Appendix B. The *first* phase was the Best Practice, which included two lab sessions. The Best Practice lab sessions were delivered at the early part of the semester to help students develop productive teams using the collaborative technologies they learned in AIDE. The *second* phase was the Project Planning period. This period started from the completion of the second lab in the Best Practice phase to the due date for all project teams to submit their two-page PDR plan. During this period, student project teams were required to plan and make their team decisions on things such as team management structure, team meeting schedules, project initiation plan, tasks at each project stage, task due dates, and other task-related issues. Although instructors provided some guidance during the course lectures regarding how to do project planning as a project team, each team was on their own to make decisions on issues like project planning, temporal or task management, resource sharing, and task allocation. The *third* phase was for each project team to work toward preliminary design review (PDR). During this period, each team was required to complete a preliminary design for the given design problem and to prepare a course presentation for the PDR. The *fourth* phase was for each project team to work toward critical design review (CDR). During this period, each team was required to complete their final design based on the feedback received in the course PDR and to prepare a course presentation for their final critical design review (CDR).

Interdependent Task Structure

The CED course possessed the following design features to promote interdependence in students' behaviors as well as raise challenges in areas like coordination and time management: (1) students were evenly assigned into two different DSTs based on their preference. By doing so, instructors created knowledge, skills, and resource interdependence among students who followed different DSTs, (2) the engineering design problem was structured as a highly-interdependent task because it could not be solved without student knowledge and skills obtained from both DSTs, (3) the course task was a complex engineering design project, which required a semester (12 weeks) to complete; therefore, coordination of team members' individual schedules across the two institutions could be a challenge, (4) although instructors provided occasional guidance about project planning and team management, students were grouped into distributed project teams focusing on problem-solving, which mimics typical, authentic project teams, meaning the reason for teams to be composed was for the purpose of the course and particularly for completing the project. These project-based teams had a high degree of autonomy in deciding their management structure, problem-solving steps (Alper, Tjosvold, & Law, 1998), and strategies to coordinate their collective efforts to complete the tasks, (5) students in the design project teams were senior college students who were dealing with varying temporal demands and constraints outside of this course, such as other academic obligations or job searching, and (6) the course was embedded in a typical computer-supported collaborative learning (CSCL) environment, implying that learning and adapting new technologies may add more time pressure to each of the teams.

As proposed by Caruso and Woolley (2008), "structural interdependence was present in the task because solving the problem required integration across analyses of the different kinds of evidence” (p. 259). Course features (1) and (2) (see above) suggested that the CED course project was designed for students to be dependent on their partners’ knowledge obtained from different DSTs. Integration of interdependent knowledge continued at every stage of the problem-solving through activities like brainstorming or evaluating alternative solutions. Students were given opportunities to pool their unique knowledge with other team members and learn about knowledge from students who attended different DSTs. They also needed to inform or be informed about the learning schedules and progress of each DST in order to plan team project progress and meet project deadlines.

Course features (3), (4), (5), and (6) suggested the time constraints and management challenges each project team was facing during the semester. These four course features also implied that initial planning, management and coordination of members’ efforts, and temporal scheduling may be critical to the effectiveness, productivity, and completion of the course project.

Research Method

Two Instrumental, Analytic Case Studies

This study was designed as an instrumental, descriptive case study research by examining and comparing two newly-formed college student project teams’ collaborative behaviors when students were working together on an interdependently-structured engineering design project. In addition, individual and team performance data were reviewed and compared to explore possible association between behaviors and performance.

As Stake (1995) suggested, a case serves to help understand phenomena within the case context in the instrumental case study. The cases were not the main interest of this study. The main interest was to depict students’ individual behaviors as they were working in collaborative project teams; further, to investigate how individual behaviors influenced team behaviors and collaboration. Whether interdependence emerged and developed from students' individual behaviors during each team's collaboration process was also examined.

A prior course evaluation study (Koszalka & Wu, 2010) and research investigation (Wu & Koszalka, 2011) had been conducted on this course. I served as an evaluation team member and research assistant on those two studies. In these two previous studies, two all-male teams (Alpha and Gamma) were selected in order to eliminate potential gender effects on collaboration. The previous two studies revealed differences between the two teams on task activities, technology choices, and team dynamics. The findings from the two previous studies provided motivation to investigate more deeply concerning whether students in the two teams may appear varying individual and/or team behaviors in other areas during their collaboration processes and to explore whether different behaviors may be associated with team performance differences, if being identified. Thus, the same two teams were used as the analytic cases for this study. Using the same teams helped form a more complete understanding of how students' individual behaviors may be related to team collaboration and performance.

Data Source

Selected recorded SameTime team meeting videos were used as primary data sources for this study because students' major interactions occurred during their project team meetings in SameTime (ST). Yin (2014) suggested that case study researchers should focus on analytic generalization and "avoid thinking in such confusing terms as 'the sample of cases' or the 'small sample size of cases'" (p. 42). Therefore, in order to provide a sound basis for analytic generalization as well as to track team behavior trends longitudinally, three videos were purposively selected for each of the two teams, one video randomly selected from each of the first three course phases described above (i.e., the phases of Best practice, Project planning, and Preliminary design review).

Additional data sources included (1) student performance data containing individual DST performance data, team final project evaluation and grades, and peer-/self-assessment data, and (2) course-related materials containing the course syllabus, course lecture presentations, and other course documents.

No video was selected from the fourth course phase. This is because (1) the first three phases happened at the first 60-70% of the course provide sufficient data to examine individual and team behaviors. Information gathered from the first 30-40% of the course helped to investigate teams' initial behaviors. Data gathered from the second 30-40% of the course offered opportunities to observe whether students' behaviors changed or continued, and (2) the number of recorded videos in the fourth phase was limited and available videos were not in good quality for data collection. In order to examine whether the observed changes continued, increased or decreased to the end of the course, peer assessment data were used as supplementary information. Peer assessment data were collected twice: the first set of data was gathered at the time when PDR was due (the completion of the third phase) and the second set of peer assessment data was collected at the end of the course (the completion of the fourth phase). Comparing the two sets of peer assessment data offered meaningful information regarding members' perception of whether their peer members' task-related work efforts and contributions to the team changed or not.

Two instruments were developed for behavior data collection and analysis. First, the *Interdependence Rating and Observation Scheme* was used to collect individual student and team behavior data, calculate interdependence scores, and gather additional observation notes from monitoring each of the selected meeting videos. Second, the *Collaboration Conversation Analysis Categories and Micro-analytic Map* was used to categorize video conversation transcript data by identifying specific communication and planning behaviors and decision-making activities and strategies. Compared with those tools which simply calculate the number and frequency of collaboration behaviors (Wageman & Baker, 1997), the process-oriented research approach using the two designed instruments in this study allowed me to obtain more fruitful evidence of collaboration during the teamwork process. Information regarding the development and validation of the two instruments is detailed in Chapter 3.

As an inside observer of the course in the two prior studies, I was familiar with the team composition and members' behaviors in participating in on-task activities and technology choices. Therefore, I may have brought some subjectivity when I interpreted the data. Therefore, a second rater was recruited. The second rater helped code and analyze the data. In addition, information collected from meeting observation and conversation analysis, peer- / self-assessment, and team performance evaluation were triangulated to maximize the objectivity and ensure the reliability of the evidence gathered. Data triangulation helped strengthen the construct validity of a case study by developing converging evidence (Yin, 2014). In order to ensure the trustworthiness of collected rating, observation, and conversation data, double-coding was also implemented for each of the selected videos. Data collection and analysis procedures are described in Chapter 3 of this study.

The Analytical Concept: Behavioral Interdependence

Wageman (2001) suggested a concept of *behavioral interdependence* to differentiate performers' actual behaviors from the interdependence required by the task structure. Behavioral interdependence was initially defined by Wageman as "the amount of *task-related interaction* actually engaged in by group members in *completing their work*" (p. 207).

Later, Wageman and Gordon (2005) clarified that, compared with interdependence structured in tasks (i.e., structural interdependence), behavioral interdependence emerges from the way that team members interact with each other when working on tasks. In newly-formed project teams, such emergent behavioral interdependence would gradually evolve into a "patterned, consensual behaviors of individual actors" (Wageman & Gordon, 2005, p. 688). Caruso and Woolley (2008) agreed with Wageman and Gordon (2005) on the importance of studying this emergent concept of behavioral interdependence. They argued that it is difficult to form necessary levels of collaboration through structural interdependence alone and team members need to "develop the expectation to voluntarily share and process task-relevant information with one another in conducting the team's work" (p. 255).

In this study, *behavioral interdependence* was used and proposed as associated with actual behaviors occurring in collaboration. Based on the term's previous definitions as described above, behavioral interdependence is defined in this study as:

> *Behavioral interdependence* is the extent to which team members participate in task-related actions and interactions in completing their work.

According to this definition, behavioral interdependence leading to collaboration depends on (1) whether students take actions in task-related activities and (2) whether students' actions influence each other and a team's collective behaviors towards task completion.

Analysis of Behaviors and Resultant Collaboration

Process-oriented approaches that require the examination of behaviors based on certain communication categories or psychological dimensions (Serce, Swigger, Alpaslan, Brazile, Dafoulas, & Lopez, 2011) (e.g., coding or rating schemes) are commonly observed in behavior analysis research. Such process-oriented approaches allow for better understanding of the collaboration content in its process and provides researchers opportunities to obtain more useful insights into the dynamics of the collaboration process and determine behavioral factors that are influential to better performance and increased collaboration. For instance, Roschelle & Teasley (1995) found that the process of collaborative learning is not predicable and students' engagement with collaboration activities sometimes diverged and later converged. In this study, students' actual behaviors and resultant collaboration were analyzed in three aspects of the collaboration process: communication, planning, and decision-making. Table 1 summarizes the three analytical aspects and the selected variables under each aspect. A short description of variables researched in each of the three aspects is provided in the following paragraphs.

Table 1-1

Three Analysis Aspects of Interdependent Behaviors in Collaboration

Behavioral interdependence in Team Communication	• Participation • Turn-taking & Collaboration flow • Repair
Behavioral interdependence in Team Planning	• Task management • Temporal planning
Behavioral interdependence in Team Decision-making	• Joint information pooling • Reaching agreement

Behavioral Interdependence in Team Communication

As described above, collaboration, by its nature, is interdependent. Such interdependence exists in both the collaboration process and outcomes, and at different aspects (e.g., participation, decision-making, resources and information sharing) and stages of collaboration (e.g., pre-collaboration design, initial planning stage).

Participation, turn-taking and collaboration flow, and repair were selected as the three indicators to examine a team's communication behaviors. In high levels of interdependent tasks, participation from all members is demanded by structured task features (e.g., resource reliance due to information, knowledge, and skills distributed among members). The task cannot be successfully achieved if any information is not shared or efforts are withdrawn. *Turn-taking* is an indicator of team members' participation and contribution to shared meaning-making (Roschelle & Teasley, 1995) as in collaborative conversations. In computer-supported collaborative learning (CSCL) environments, communication is not limited in conversational turn-taking. The fluency of communication is supported and maintained by several synchronous technologies and applications. Coherence in team communication, which is supported by cross-referencing all actions in the chat, whiteboard, sharing applications, and utterances, kept *collaboration flowing* (Meier et al., 2007). However, the collaboration flow can be easily broken due to issues such as technology breakdowns or incoherency in information delivered through different communication channels. Therefore, it is necessary for collaborators to make attempts or actions to *repair* broken communication through clarifying his/her points of view and resolving misunderstanding in order to keep communication fluency.

Behavioral Interdependence in Team Planning

In a study regarding online collaboration behaviors, Serce, Swigger, Alpaslan, Brazile, Dafoulas, & Lopez (2011) found that one of the most frequent activities that appeared in their study groups was planning activities. Planning is the key activity for a team to attain its goal (Locke, Durham, Poon, & Weldom, 1997) and teams engaging in collaborative planning tended to have more effective information integration and enhanced analytic performance (Wolley, Gerbasi, Chabris, Kosslyn, & Hackman, 2008). As in an interdependently-structured task, resources and skills are designed to be distributed among collaborative students. Therefore, a team's collaborative task-planning is dependent on members' shared expertise, skills, resources, and schedules and actions being taken. In addition, a team's effective temporal planning, especially at the initial stage of team collaboration, can promote a team's awareness "of time and deadline then by completion of an absolute amount of work in a specific developmental stage" (Gersick, 1988, p.9). Therefore, as for understanding behavioral interdependence in team planning, task and temporal planning are selected as the two variables to collect information related to students' behaviors in task management, scheduling, and time management.

Behavioral Interdependence in Team Decision-making

Team collaborative problem-solving involves a series of decision-making activities, which rely on joint information processing (Meier et al., 2007). As Johnson and Johnson (1989) suggested, efficient and effective exchange and processing of information should be heavily emphasized when analyzing student behaviors in collaboration because "the most common resource shared and exchanged … is information" (p. 65). In this study, *information pooling* and *reach agreement*, the two joint information processing phases, are proposed for examining a team's joint decision-making behaviors and activities.

Due to the reliance students have on complementary knowledge, skills, and resources in collaborative problem-solving, students are expected or required to *pool* and process their complementary knowledge and resources during team information processing (Meier et al., 2007). Information, knowledge, and perspectives constantly exchanged among students facilitate a team to reach mutual understanding and enlarge a "common ground" of shared information, concepts, perspectives, procedures, and expectations (Meier et al., 2007; Rummel, Deiglmayr, Spada, Kahrimanis, & Avouris, 2011). With information being shared, mutual understanding is expected to be ensured and constantly checked among collaborators in order for them to *reach agreement* for certain decisions needing to be made. It is interesting to examine how a team reaches agreement regarding specific team decisions, such as the development of certain criteria to ensure teamwork quality.

This section described and summarized the three collaboration aspects in which student behaviors were investigated. Issues related to analysis and evaluation of student collaborative behaviors are briefly introduced as follows.

Issues Relevant to Behavior Data Analysis

When students' collaborative behaviors are viewed as interdependent, actions such as explanation, argumentation, elaboration, or questioning should not simply be viewed as interactions between a speaker and a listener. Rather, these interactions contribute to the team information processing (Meier et al., 2007) and are "individuals' simultaneous or sequential actions that affect immediate and future outcomes of other individuals involved in the situation" (Johnson & Johnson, 2005, p. 292). Further, simply viewing collaboration as a series of interdependent behaviors is not adequate to understand collaborative problem-solving. Interdependent behaviors in collaboration should be analyzed as a team product that affects other members' further actions and contributes to the resolution of the problem. Every collaborative behavior and activity must be included as an indispensable component with other activities throughout the problem-solving process. For instance, explanation should not be considered as something delivered by the explainer to the explainee (Baker, 1994). Instead, from a 'team' perspective, explanation is constructed jointly and interdependently by both partners through behaviors and strategies such as asking, clarifying, arguing, and explaining, in order for both parties to understand each other. In this process, the entire team can also benefit from these behaviors and strategies because other members may have similar understanding gaps. Therefore, it is suggested that behaviors, like raising questions, clarifying confusions, offering explanations, and exchanging opinions, are actions to support the establishment of common ground of team understanding and contribute to team knowledge building.

Summary and Significance Statement

In this study, I argue the necessity to investigate students' actual behaviors in the collaboration process for the purposes of understanding the emergence and development of behavioral interdependence. Further, research questions ask how students' individual behaviors influence other's actions, team performance, and overall team collaboration. Behavioral interdependence was selected as the major analytical concept based on information drawn from prior literature. Student behaviors in communication, planning, and decision-making were selected as primary sources of evidence for behavioral data collection and analysis.

Examining students' actual, collaborative behaviors helps provide a mechanism to monitor the team working processes and better understand how interdependence emerged and developed over time. In addition, examining students' actual behaviors in collaboration extends our understanding of students' behavior differences at varying collaboration levels and provided opportunities to gain more useful insight into the dynamic nature of the collaboration process. Studying behavioral interdependence promoted the development of new aspects of social interdependence theory and provided heuristic utility to the research in interdependence and collaboration. As described above, the interdependence among team members could vary which suggests that the dynamic relationships among participating students likely change over time. Studying behaviors and interactions therefore should be a longitudinal process because the form of student interaction may continue to evolve over time or change when certain situations arise.

Results of this study are expected to help instructors and instructional designers form better understanding of team collaboration and team functioning so that they may bring more informed, appropriate instruction to facilitate students' learning of communication and collaboration skills, especially in solving complex, interdependently-structured tasks.

This study attempts to fill a gap in the theoretical understanding of behavioral interdependence during the collaborative process. To accomplish this goal, a thorough examination of students' actual behaviors toward joint problem-solving and exploration of the emergence and development of behavioral interdependence during the collaboration process was completed. Relevant literature on interdependence in collaboration is further summarized in Chapter 2 discussing research needs, clarifying noted confusion among concepts, and visiting major variables in the theories.

CHAPTER 2 LITERATURE REVIEW

Introduction

Current job markets demand that college graduates have good interpersonal skills, demonstrate proficiency in using technology to communicate and solve problems, understand team dynamics, and work effectively in teams (Serce, Swigger, Alpaslan, Brazile, Dafoulas, & Lopez, 2011). Therefore, university educators have been pressed to design and deliver instruction that can instruct and facilitate students in obtaining proficiency in communication and collaboration, especially when students are required to work in distributed learning environments. Collaborative learning or team learning, therefore, has become a common pedagogical strategy used in university and college instruction.

However, it is observed that "along with the increased use of groups has been significant confusion over how to design them: teams have been created where they are not appropriate and introduced in ways that assure their failure" (Wageman & Baker, 1997, p. 140). Much of this confusion may stem from a failure to understand the interdependent nature of teamwork and its dynamic process and the difficulty in distinguishing different teamwork formats such as collaboration and cooperation during the instructional design process; therefore, leading to inadequate and inappropriate design of task features and reward systems.

Interdependence presents the dynamic nature of teams and distinguishes teams from collections of individuals (Bonito, 2002). Some researchers recommended that knowledge about interdependence is beneficial to understanding of team learning and can be used to advize training and offer skill learning suggestions (Alper, Tjosvold, & Law, 1998). Interdependence can be differentiated as structural interdependence and behavioral interdependence. Structural interdependence refers to interdependence designed in task structures such as in task goals, rewards, definitions, and resources. Behavioral interdependence emerges from student behaviors during the collaboration process. Social interdependence theory suggests that when students perceive tasks as (highly) interdependent, they are encouraged to behave collaboratively and engage in promotive interaction. The similar idea is introduced by Wageman and Baker (1997) that highly interdependent tasks may drive team-like behaviors. Based on this idea, structural interdependence has been practiced in both field and lab settings with an intention to promote students' collaborative behaviors so that (positive) interdependence can be actually established and developed during the collaboration process (i.e., behavioral interdependence). Nevertheless, design of interdependent tasks does not always guarantee the occurrence of students' team-like behaviors during the collaboration process (Wageman, 1999). The relationship between structural interdependence and teamwork process is complex and has not been conclusively established (Courtright, Thurgood, Stewart, & Pierotti, 2015). On the other side, behavioral interdependence is a variable which "essentially captures behavioral process" (Courtright, et al., 2015, p. 1827) and behavioral process dynamically changes. For instance, when a team member senses that the collective goal is no longer aligned with his or her own priorities, the team member may withdraw his or her efforts. Therefore, Wageman, Gardner, and Mortensen (2012) suggested that, instead of asking about the level of interdependence in a team or whether the team works as a real team, it may be more helpful to ask "how is interdependence evolving in this collaboration over time?" or "do members exert effort as they are truly working as a team" (p. 307)?

Therefore, the purpose of this study was to conduct a longitudinal observation and examination of individual students' actual team-like behaviors through the concept of behavioral interdependence as they were collaborating on an interdependent engineering design task in a distributed project team. Questions related to how individual student behaviors are associated with team behavior patterns, overall collaboration, and team performance were also explored. As Chapter 1 addressed major research needs, Chapter 2 adds more evidence to the theoretical underpinning to support the arguments presented in Chapter 1. This chapter begins with a discussion of engineering education's urgent call for changes in curriculum to more effectively incorporate teamwork in complex task settings (e.g., to complete high levels of interdependent tasks in distributed environments such as on the self-managed project teams in this study). This discussion sets up the context for this study. The chapter then introduces the concept of interdependence, reviews its definition, and describes its varying forms. Based on the concept of interdependence, a distinction of collaboration from cooperation, two concepts frequently confused and used interchangeably in course design, is highlighted as an illustrative example to demonstrate that differently-structured interdependence in tasks can result in different behaviors and skills and consequently influence a team's functioning and performance. The discussion continues to summarize existing literature related to effects of structural task interdependence on behaviors and team functioning and argue for significance of examining student behaviors and interactions during the team-work process. Such discussions provide continuous arguments for the necessity of this study and call for process-oriented instruments to capture behavior data at a micro-analysis level. The chapter ends with a detailed review of three existing instruments that were selected as the foundation for the two instruments designed of this study. Chapter 2 concludes with a chapter summary and a brief introduction to Chapter 3.

Reality Calling: Engineering Education vs. Engineering Practice

Engineering design is a “highly diverse social activity” (Thomson, Stone, & Ion, 2007, p. 204). Engineers face complex design problems that require using different engineering technologies and skills to optimize consumers’ needs and satisfaction. Based on such facts, collaboration among multiple disciplines is commonly observed in engineering design and problem-solving. Thomson, Stone, and Ion (2007) studied the distributed team design by observing the collaborative behaviors of four actual industrial engineering working teams within the same organization. In their study, the authors identified that, as more challenging market requirements emerge, and more complex systems and higher levels of knowledge are required to meet design process needs, there has been an emergence of distributed design teams. Distributed team decision-making requires well-built information infrastructures that can support effective design activities as well as satisfy individual input and judgment needs within a group of designers (Yoshimura & Takahashi, 2001; Chiu, 2002). Although information networking technology (e.g., video-conferencing) can make the communication more efficient, the distance can still lead to collaborators less likely to work effectively together due to reasons such as inadequately-developed information infrastructures or insufficient skill/knowledge/training support for distributed collaborative work, which may further result in less trust and more difficulty in information access (Thomson et al., 2007). In addition, when the number of team members participating in the design process increases, the design process and communication tend to become more complicated. Therefore, compared with face-to-face teamwork, collaborators working in distributed design teams face more challenges in coordinating schedules, facilitating communication, sharing information, and exchanging opinions.

Meanwhile, college engineering students are not well-prepared for this type of workplace engineering work (Jonassen, Strobel, & Lee, 2006). Workplace engineering design problems are ill-structured (Jonassen, 2000; Uribe, Klein, & Sullivan, 2003) and knowledge required to solve such problems is usually distributed among a variety of people. Engineers often engage in team work and collaborate with different personnel including engineers who may be discipline experts, technical professionals (e.g., draftsperson, survey designers), or administrators (Jonassen, et al., 2006). To cope with these challenges, students need to master the disciplinary knowledge and learn to analyze ill-structured problems while working with diverse groups of people who have differences in opinions and communication strategies. In Jonassen, Strobel, and Lee's study of the differences between real workplace engineering problems and the class problems used in engineering education courses, the interviewed workplace engineers strongly recommended that communication skills need be included in engineering curricula (Jonassen, et al., 2006), especially in client interaction, making oral presentations, writing, and ability to deal with ambiguity and complexity. The authors therefore encouraged instructors to create more meaningful collaborative learning experience based on criteria such as whether the collaborations "foster positive interdependence, individual accountability, promote interaction, social skills, and co-construction of knowledge" (p. 148). This suggestion implies that college educators' failure to create successful collaborative learning experience may be due to educators' inadequate knowledge and understanding of collaboration and its interdependence nature. Because of educators' inadequate knowledge, they may confuse with different teamwork formats (i.e., collaboration vs. cooperation) and choose inappropriate task features for their teamwork design.

Interdependence has been suggested to be one of the most powerful team design features (Courtright, Thurgood, Stewart, & Pierotti, 2015) and a driver of team-like behaviors and team effectiveness (Wageman, 1999). Although the concept has been largely investigated in social psychology (Johnson & Johnson, 2009) and organizational behavior fields (Wageman, 1999), it is not frequently visited and practiced in the area of instructional design. Therefore, in the following section, an overview of the concept of interdependence is presented, a synthesis of the literature addressing effects of interdependent task design on behaviors is provided, and issues and research gaps are noted that guide this study.

Conceptual Underpinning

Interdependence

Interdependence is proposed as the essence of a team and formed among members (Lewin, 1948). It distinguishes a team from a collection of individuals and results in a team "being a dynamic whole so that a change in the state of any member or sub-group changes the state of any other member of [the] subgroup" (Johnson & Johnson, 2009, p. 366). In recent years, interdependence has been identified as "a central aspect of team design" (Courtright, Thurgood, Stewart, & Pierotti 2015, p. 1825) in the field of organizational behaviors. There had been increasing attention to interdependence in organizations with an expectation that such interdependent structures could foster people's interdependent work and generate outcomes that promote productivity, efficiency, and performance quality (Wageman, 1999).

Meaning and forms of interdependence.

Historically, interdependence has been given many definitions: the meaning, dynamics, and consequences of the term show a lack of clarity (Wageman, 1999; Courtright, et al., 2015). For instance, some researchers (e.g., Shea & Guzzo, 1987) define interdependence as the level of task-motivated interactions among team members. Other researchers (e.g., van de Ven, Delbecq, & Koenig, 1976) proposed the meaning of interdependence is the extent to which team members must actually work together to perform the task. The first definition by Shea and Guzzo clearly implies that the interdependence emerges after team members actually carry out the project during the execution process and is a behavioral construct (Courtright, Thurgood, Stewart, & Pierotti, 2015); whereas the second definition apparently treats interdependence as a task design feature which requires close teamwork among members.

Interdependence arises in areas such as goals, rewards, tasks, roles, skills, resources, and technology (Gonzales, 2010). Wageman (1999) clarified and grouped different forms of interdependence into two higher order of constructs, (1) structural interdependence (what is *structured in*) and (2) behavioral interdependence (how people *actually behave*). Structural interdependence relates to design features that can be manipulated to create interdependence structure. Behavioral interdependence refers to how team members actually act and interact when they are engaged in task-related work. Based on Wageman's categorization of interdependence, an interdependence categorization chart is provided below (see Figure 2-1 below) to help visualize the concept of interdependence, its two construct variables, and forms of interdependence under each construct.

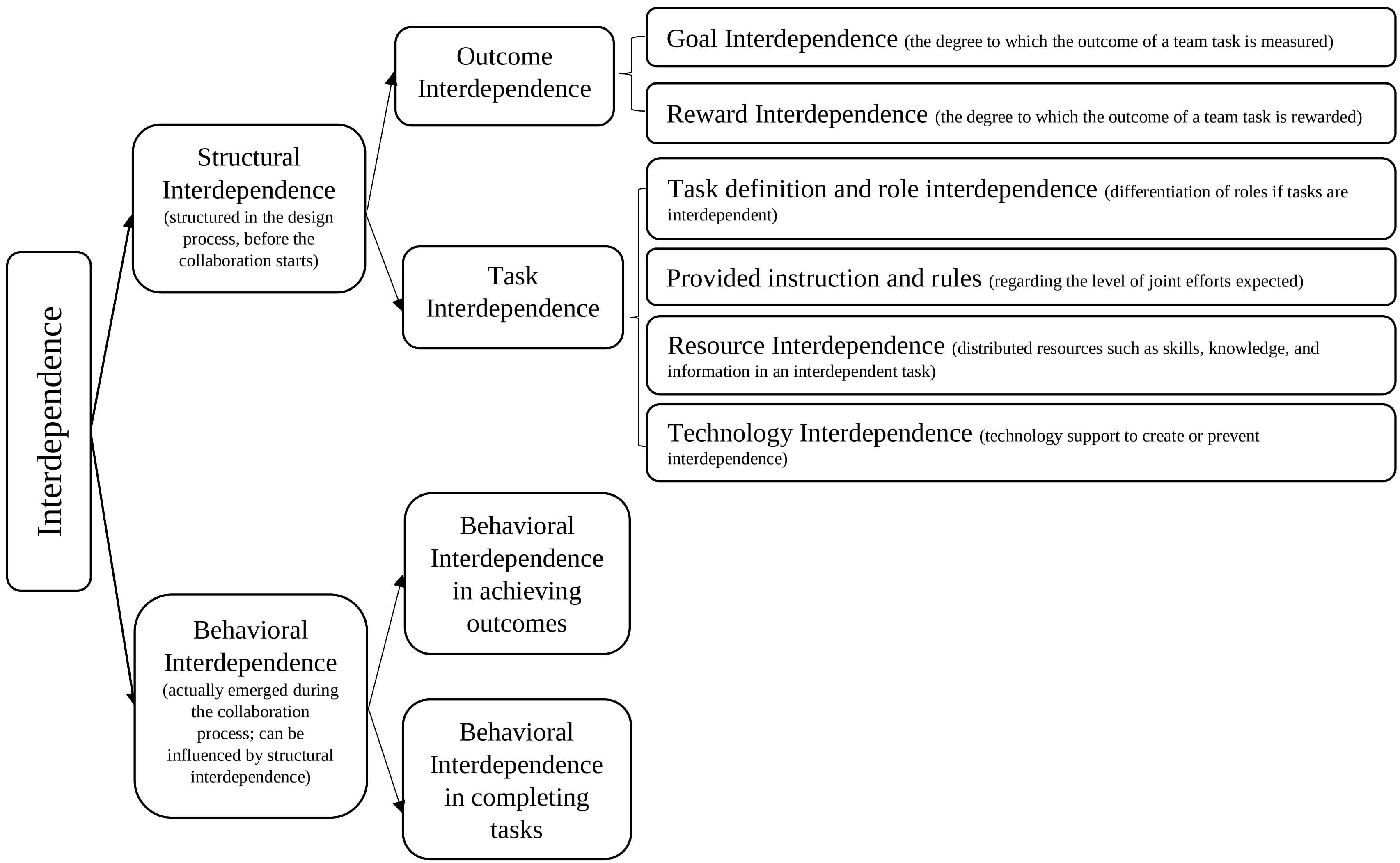

Figure 2.1. Interdependence Categorization Chart.

Structural interdependence.

As described above, structural interdependence is associated with how the work is designed, referring to “features of the work itself, how goals are defined, how rewards are distributed, and so forth” (Wageman, 2001, p. 198). Structural interdependence can be further divided into structural task interdependence or task interdependence (interdependence around work inputs) and structural outcome interdependence or outcome interdependence (interdependence around work outcomes).

Task interdependence is the degree of collective action that a task requires to complete (Wageman, 1995). Task interdependence includes consideration of these elements in a task design process: (1) how the work/task is defined, including whether tasks should be defined to members as individual, interdependent, or mixed work (meaning part of the task require individuals and another part of the work requires collaboration) and the differentiation of roles if tasks are interdependent (role interdependence), (2) how instructions and rules about the work process are given, including instructions and rules provided to students regarding the level of joint efforts expected of them and how students should coordinate their efforts, (3) technology support of the work. For instance, the task technology supporting simultaneous action by team member can create interdependence (e.g., play group videogame) or prevent it (e.g., the assembly line often requires independent work of every individual worker in a TV factory), and (4) necessary resources for completing a task, such as skills and information. Distributed resources can create interdependence. When resources, skills, or information are distributed, individual team members are encouraged to seek access to and share these distributed resources with each other, which create interdependence. It is necessary to note that the interdependence created from resources depends on the nature of task definition.

For instance, gastroenterologist, nurses, and medical assistants closely work together and depend on each other's special knowledge and skills (to collaborate) when operating an upper gastrointestinal endoscopy. When they are seeing an individual patient in the hospital for a routine visit, they usually work independently. When a person visits a gastroenterology specialist, the nurse takes the person from the waiting room, measures the person's weight, blood pressure, and heartbeat, guides the person to the patient room, and asks a few questions before the gastroenterologist sees the person to perform an exam. The task interdependence among team members is defined by these four elements (i.e., task definition, instructions, technologies, and resources) together; therefore, it is reasonable to expect that the degree of the interdependence, structured in these four elements, sets the stage for collaborative behaviors to occur and affect team performance (Wageman, 1999).

Outcome interdependence refers to "the degree to which shared significant consequences of work are contingent on collective performance of the task(s)" (Wageman, 2001, p. 201). Outcome interdependence is a combination of goal and reward/feedback interdependence. Courtright et al. (2015) described outcome interdependence as the degree to which the outcome of a task is measured (goal interdependence), rewarded (reward interdependence), and communicated (feedback interdependence) at the team level so that collective efforts, not individuals' simple contribution, are underlined. Outcome interdependence does not have to be designed along with task interdependence. Outcome interdependence can simply mean that team members share a common goal or are evaluated as a collective unit, regardless of whether they *actually* work together. In a task interdependence situation, members must *actually* work together (Mitchell & Silver, 1990).

Behavioral interdependence.

Behavioral interdependence regards how people actually behave when they are executing the work. It is specifically associated with the degree of *task-related* interactions that team members are actually engaged in when working together to complete their work (Wageman, 1999; Wageman, Gardner, & Mortensen, 2012). Since structural interdependence can be divided into outcome and task interdependence, I distinguish behavioral interdependence in achieving team outcomes and behavioral interdependence in completing tasks. The behavioral interdependence in achieving team outcomes reflects how members actually behave when reacting to the task design that their interdependent, collaborative efforts are measured and rewarded. The behavioral interdependence in completing tasks examines how members actually behave when they enter a task situation in which they individually do not possess all resources, skills, and abilities to complete the task independently and technology / instruction is structured in a way that does not encourage independent work. Because the concept of behavioral interdependent is new to the field and differentiating behaviors due to different structural interdependence is not the focus of this study, the division of behavioral interdependence (as presented in Figure 2-1) is at the conceptual level and was not applied in the data analysis.

Team members' behavioral interdependence is strongly driven by the design of structural interdependence (Wageman, Gardner, & Mortensen, 2012). By observation, members working on tasks with high levels of both task and outcome interdependence tended to have highly interdependent team behaviors; while members working on individual tasks with low levels of both task and outcome interdependence were usually observed to work independently. Therefore, Wageman (1999) suggested that "if the aim of team interventions…is to develop high behavioral interdependence among individuals doing a task, it is important to identify the conditions that lead to team-like behaviors or working together to complete a task" (p. 208). In the following section, I first distinguished collaboration from cooperation as an illustrative example, by using the concept of interdependence, to reveal that different levels of task interdependence could result in varying levels of teamwork behaviors. Second, I analyzed the structural characteristics of the CED course. I summarized the ways in which CED course was pre-structured to ensure promoted collaboration as opposed to cooperation (i.e., how structural interdependence was built in CED course).

Collaboration and cooperation: two distinct interdependence designs.

The terms "collaboration" and "cooperation" are commonly used interchangeably in both literature and design practice. The confusion may rise from a common feature shared by the two concepts that both scenarios require a collective effort among the team members. However, collaboration has different definitions and requires different task design structures from cooperation and each form describes different "degrees to which a task requires collective action" (Wageman, 1995, p. 146).

Collaboration has its Latin roots in "labor," implying participants co-labor towards a same goal. Collaboration requires team members to mutually participate in a coordinate effort and tackle the problem together, each using his or her own knowledge, skills, experiences, or perspectives to resolve some aspects of the problem with the support of other team members. On the other hand, the etymology of the word 'cooperate' is in the Latin word "opera," which implies carrying something out or making something happen. Cooperation was regarded as team activities being carried out by dividing tasks among participants and each person accounts for a portion of the problem-solving (Roschelle & Teasley, 1995).

Collaboration and cooperation also differ in the way in which a task is carried out. Collaboration implies more active involvement among team members. It requires participating parties to share resources and responsibilities while jointly solving problems. When a task is divided into sub-tasks, subtasks frequently require collective cognitive effort from multiple team members. On the occasion when a sub-task can be done by an individual, a collective effort from part or all other team members is required to bring sub-tasks information into a synthesized final product. In this part of the collaborative process, critical evaluation of sub-task information, establishment of certain criteria to assess the final product and effective communication are especially important. On the other hand, a task in cooperation is split into subtasks which can be accomplished by an individual independently (Dillenbourg, Baker, Blaye, & O'Malley, 1996). In cooperative tasks, coordination is simply required when assembling partial results while cooperative parties maintain their separate mandates and responsibilities. In other words, participants can simply complete their tasks without proactive engagement in the interaction with other team members.

Putting students in a wrong teamwork format (e.g., putting students in a cooperative learning setting when collaborative learning is actually expected) would threaten the students' abilities to develop effective collaborative skills. To understand this effect, it is necessary to understand the interdependence nature as well as distinct design procedures/requirements for collaboration activities versus those for cooperation activities.

Collaboration is distinct from cooperation based on the four task interdependence elements described above: (1) how the work is defined. Both cooperation and collaboration require collective work, meaning the work demands multiple individuals to complete. However, cooperative work only requires sequential synthesis of all the parts with rare interactions among members. Collaboration requires simultaneous interactions among members; (2) how instructions and rules about the work process are given. Since cooperation does not involve interactive discussions among members, its subtasks are usually done by individuals. The final product is completed when each part is finished along the line (e.g., assembly line). Collaboration, on the other side, requires a great amount of interaction such as information sharing, exchanging ideas, and negotiations. The level of joint actions is highly expected in collaboration; (3) technology support of the work. Technology used in collaboration for either communication or problem-solving purposes demands simultaneous actions by members. However, technology used in cooperative work usually prevents synchronous efforts; and (4) how resources are distributed. Resources can be distributed in both collaboration and cooperation. In collaboration, distributed resources must be shared in order for the team to operate jointly. However, in cooperation, performers do not necessarily share their resources and in most situation, they may rarely share. Therefore, based on the description of different types of interdependence, cooperation can be categorized as low interdependence work and collaboration can be defined as high interdependence work. The four task interdependence elements differences between collaboration and cooperation are summarized in Table 2-1.

Table 2-1

Task interdependence differences between collaboration and cooperation

Task interdependence	**Collaboration**	**Cooperation**
Task definition	Demands collective work which requires simultaneous interactions among members	Demands collective work which requires sequential synthesis of all the parts with rare interactions among members
Instruction	High levels of joint actions are especially expected, emphasizing great amount of interaction such as information sharing, exchanging ideas, and negotiation	Subtasks are done by individuals and the final product is completed when each part is finished along the line
Technologies	Technology used in collaboration demands simultaneous actions by members	Technology used in cooperative work usually prevents synchronous efforts
Resources	Resources are distributed among members and must be shared in order for the team to operate jointly	Resources are distributed among members but are not necessarily shared; in most situations, they are rarely shared

Confusion between collaboration and cooperation can hamper the instructional design of suitable instructional strategies. Students can be provided with improper knowledge or experience about collaboration by being put in an actual cooperative environment. For instance, Eaves (2007) observed that many online projects labeled as “collaboration” (e.g., open-source software projects, wiki information composition and edition) were instructing learners to break problems down into small tasks which were addressed by individual team members who rarely needed to talk and exchange ideas with each other. Such so-called collaborative projects are actually cooperative. Research studies have strongly supported that different design features in tasks do result in changes in behaviors, team functioning, and performance (e.g., Aube & Rousseau, 2005; Hackman, 1969; Raven & Shaw, 1970; Rico, Alcover, Sanchez-Manzanares, & Gil, 2009; Shea & Guzzo, 2003; Wageman, 1995). Therefore, it is reasonable to argue that putting students in the *wrong* teamwork environment may prevent them from obtaining good teamwork experience and more importantly, limit their learning of appropriate collaborative skills.

Structural interdependence built in CED course.

The CED course was structured with high levels of interdependences to promote students' collaborative behaviors. These structural interdependence features were analyzed and described in Table 2-2. These features may also raise challenges in areas like coordination and time management.

Table 2-2

Structural Interdependence of CED course design

Task interdependence: the degree of collective action that a task requires to complete (Wageman, 1995)	
1) How the work/task is defined	The design project was structured in a way that requires student knowledge and technical skills obtained from both DSTs
2) How instructions and rules about the work process are given, including instructions and rules provided to students regarding the level of joint efforts expected of them and how students should coordinate their efforts	○ The instructor informed about teamwork and encouraged joint efforts in collaboration ○ The instructors offered lectures on team-building skills ○ The instructors provided specific instruction on how to do team plans ○ The instructors provided meeting schedule samples to encourage joint efforts in taking routine tasks
3) Necessary resources for completing a task, such as skills and information	Built-in distributed resources: team members were evenly divided into two different DSTs based on their learning interests. By doing so, instructors created knowledge, skill, and resource interdependence among members who followed different DSTs in a team
4) Technology interdependence: whether technology supporting simultaneous actions	AIDE and SameTime system included both synchronous and asynchronous tools to support communication and design activities
Outcome interdependence: the degree to which shared significant consequences of work are contingent on collective performance of the task(s) (Wageman, 2001, p. 201)	
1) Goal interdependence	The design project is measured at the team level
2) Reward interdependence	The design project is graded at the team level
3) Feedback interdependence	The instructors provided feedback at the team level so that collective efforts, not individuals' simple contribution, are underlined

As a summary, team features have powerful effects on behaviors and team functioning (Fan & Gruenfeld, 1998; De Dreu, 2007). Hackman (1969) stated that "tasks play an important role in much research on human behavior, and differences in tasks and task characteristics have been shown to mediate differences in individual and social behavior" (p. 97). For instance, a task designed with high resource interdependence poses a requirement for team members to have intensive task-driven interaction in order to access critical information from each other for effective problem-solving (Fan & Gruenfeld, 1998). In contrast, people who are given individual work have much independence to use their unique knowledge, skills, and resources to accomplish a goal according to their own paces. The following section therefore describes how structural interdependence design can change individuals' behaviors and how a team functions.

Effects of structural interdependence on behaviors.

The role of both task and outcome interdependence on process behaviors and team functioning has been demonstrated through theory and by empirical studies (Wageman & Gordon, 2005; Fan & Gruenfeld, 1998). Some researchers proposed that task interdependence and outcome interdependence work independently from each other and affect behaviors and performance by influencing different aspects of team functioning (e.g., Courtright, Thurgood, Stewart, & Pierotti, 2015; Someche, Desivilya, & Lidogoster, 2009; Wageman & Baker, 1997). While other researchers support the idea that the effect of outcome interdependence is contingent on the level of task interdependence based on their belief that task interdependence still plays the primary role in influencing behaviors and performance (e.g., De Dreu, 2007; Fan & Gruenfeld, 1998). In following paragraphs, the effects of each of the two interdependence on behaviors and team performance are discussed in turn.

Effects of task interdependence: In high task interdependence conditions, task structure demands (e.g., resource interdependence) members to participate in intensive task-driven interactions and communications to access critical information that help them understand a given problem and generate ideas. Therefore, communication behaviors, such as explanation, negotiation, and persuasion, are expected to be displayed during high interdependent task conditions. Literature has shown that members working on tasks with high interdependence have significantly increased behaviors in cooperation (Lee, Lin, Huang, Huang, & Teng, 2015; Wageman, 1995), effective information or knowledge sharing (Lee, et al., 2015; Wageman & Baker, 1997), helping (Allen, Sargent, & Bradley, 2003; Wageman, 1995), effective conflict management (Alper, Tjosvold, & Law 1998; Lee, et al., 2015; Somech, Desivilya, & Lidogoster, 2009), working on tasks (Courtright, et al., 2015), developing and maintaining positive interactional relationships (Lee, et al., 2015), and vigilant decision-making (Fan & Gruenfeld, 1998). Fan and Gruenfeld (1998) conducted an experimental study of the relationship between resource and reward interdependence and team performance. By investigating 162 undergraduate students in 54 teams in a relatively complex task setting, the authors observed that under high resource interdependence, team members used more asking, negotiation, explanation, and persuasion for needed resources that therefore resulted in more task-driven interaction and more vigilant decision-making (Fan & Gruenfeld, 1998). Their study results also suggested that student teams working in the increased level of resource interdependence conditions completed more tasks with higher scores spending approximately 17% less time than comparison teams working under low resource interdependence conditions. Lee, Lin, Huang, Huang, and Teng (2015) investigated effects of task interdependence, team conflict, team cooperation, and trust on real estate brokers' job performance. After analyzing field survey data, the authors observed similar results that high task interdependence is significantly associated with team members' information sharing, which tended to enhance team cooperation. The authors further found that high task interdependence was associated with fewer appearances of relationship conflict, such as "interpersonal issues, political norms and values, and personal taste" (De Dreu & Van Vianene, 2001, p. 309); hence, fostered team job performance. Although task interdependence implies more intensive interaction among members, which could create more opportunities for conflicts, literature has supported that task interdependence can lead to a team's cooperative approach to disagreements and conflicts. This is likely the case because frequent communication encouraged by task interdependence can create more opportunities for members to support and help each other (Allen, Sargent & Bradley, 2003; Alper, Tjosvold, & Law, 1998; Somech, Desivilya, & Lidogoster, 2009). In their field study of 77 engineering teams in high technology firms, Somech, Desivilya, & Lidogoster (2009) collected employees' data of team conflict-management, team identity, task interdependence, and team performance based on sample teams' daily operation. The study results showed that, at high level of team identity, task interdependence was positively associated with team cooperative conflict management. This suggested that the team used a "problem-solving, collaborative, integrating, solution-oriented, win-win or positive-sum style" in dealing with team conflicts (p. 362). Teams who took the cooperative conflict management approach tended to emphasize common goals and focus on knowledge, logical argument, and explanation, which "encourages team members to examine diverse knowledge bases and explore alternative[s]" (Somech, et al., 2009, p. 362).

Regardless that task interdependence tends to contribute to increased collaborative behaviors and enhanced team performance, high levels of task interdependence can also increase task complexity and lead to process losses (Fan & Gruenfeld, 1998; Allen, Sargent, & Bradley, 2003). Tasks with too much structural interdependence may "pose problems with regard to intragroup cooperation" (van der Vegt, Emans, & van de Vliert, 2001, p. 55) and "raise the level of coordination to the point where its costs outweigh its benefits" (Wageman, 1995, p. 149). Therefore, high levels of task interdependence may lead to performance loss from group process disasters (Wageman & Baker, 1997), which can be caused by expending more time in coordination and regulation of collective behaviors and less time in completing the task itself (Fan & Gruenfeld, 1998). For instance, Allen, Sargent, and Bradley (2003) conducted a laboratory experiment to investigate the effects of task and reward interdependence on helping behaviors and team performance. In the study, the authors found that high levels of helping behaviors under high task interdependence conditions did not consistently transfer to high levels of performance. This was likely because high task interdependence imposed more cognitive complexity on members. When members perceived tasks being complex, they struggled between choosing appropriate strategies to complete the task and applying different types of communication skills for effective information sharing. Therefore, their focus on critical performance requirements and information may have been distracted and less effective (Allen, et al., 2003). With virtual teams, communication technology, which possesses capacity to support the communication and problem-solving needs required by task interdependence, may also pose unnecessary distractions and additional learning load (e.g., learning about new tools and deciding suitable and effective tools for different problem-solving contexts) to members (Rico & Cohen, 2005).

Effects of outcome interdependence: In most situations, task interdependence alone does not necessarily predict team process (Someche, Desivilya, & Lidogoster, 2009). Outcome interdependence frequently plays a role when teams work on an interdependent task. As described above, outcome interdependence is shown in forms of goal interdependence (i.e., the degree to which the outcome of a task is measured) and reward interdependence (the degree to which the outcome of a task is rewarded and communicated). Shared rewards and goals are positively related to team performance (Alper, Tjosvold, & Law, 1998; Fan & Gruenfeld, 1998; Miller & Hamblin, 1963) and members were observed to show more cooperative strategies, increased information sharing (Mitchell & Silver, 1990), and reduced social loafing (Pearsall, Christian, & Ellis, 2010). Alper, Tjosvold, and Law (1998) conducted a field survey study to examine the social processes of self-managing teams' effective problem-solving. By surveying 540 employees in 60 teams from the production department of a leading manufacturer company in the United States, the authors found that teams who perceived their goals were shared and positively related "discuss[ed] their opposing views openly and constructively" (p. 45), which contributed to the teams' decision-making, confidence development, and enhanced performance. Such open discussion of opposing opinions is called constructive controversy (Johnson, Johnson, & Tjosvold, 2006). When members perceived and believed their goals as shared, they understood one member's success is tightly related to other members' success. Thus, they welcomed ideas and appreciated each other's perspectives. Such teams were observed to use significantly higher frequency of constructive controversy and were "willing to express their ideas and positions, ask each other for more information and arguments, and try to put the best ideas together to create the most effective solution" (p. 47).

Although researchers supported that outcome interdependence, same as task interdependence, influenced members' behaviors; they did indicate that the two structural interdependences affected different aspects of team functioning (Mesch, Johnson, & Johnson, 1988; van der Vegt, Emans, & van de Vliert, 2001; Wageman, 1995, 1999; Wageman & Baker, 1997). Task interdependence affects team performance directly through members' actual collective work and action. Outcome interdependence influences performance indirectly through members' motivation (Fan and Gruenfeld, 1998). Wageman (1995) studied 800 service technicians in 152 groups in U.S. Customer Services division of Xerox Corporation. By intentionally selecting existing groups who worked on individual, hybrid, and group tasks (3 task interdependence situations), the author manipulated rewards based on group, individual, or both group and individual performance (3 reward settings) for each task interdependence situation. The author found that reward outcomes seem to influence members' motivation rather than directly affect their behaviors. Reward interdependence appears to have fostered motivation and group norms to promote efforts. Later, Wageman and Baker (1997) conducted an experimental lab study of 112 college students, testing the joint effects of task interdependence and reward interdependence (one of the outcome interdependence) on group performance. The authors had similar observations with Wageman's study (1995): although high task interdependence drove students' task behaviors, the increased task behaviors may not have resulted in enhanced team performance if high reward and goal interdependence was not included in the task design.

Further, Brownlee and Motowidlo (2011) conducted a laboratory study to test the interactive effect of outcome interdependence and accountability on task behaviors and interpersonal contextual behaviors of 240 undergraduate students who participated in a large introductory management course. By using the experimental design that crossed 2 levels of accountability with 2 levels of outcome interdependence, the authors found that outcome interdependence motivated interpersonal contextual behaviors but did not affect students' task behaviors. Courtright, Thurgood, Stewart, and Pierotti (2015) further confirmed these findings in their meta-analysis of 107 independent sample studies focusing on team structural interdependence. The authors discovered that task interdependence influenced team performance mainly through task-related team functioning (i.e., behaviors and interactions focused on planning and organizing team efforts toward task accomplishment), whereas outcome interdependence influenced team performance through relational team functioning (i.e., managing interpersonal dynamics and bolstering prosocial motives to build and maintain harmonious relationships).

Meanwhile, other researchers (e.g., Fan & Gruenfeld, 1998; De Dreu, 2007) pointed that the effect of outcome interdependence was contingent on the effect of task interdependence. This is likely because designed task interdependence strongly influenced members' perception of the outcome interdependence; however, outcome interdependence did not seem to have such effects on members' experiences of the task (Wageman, 1995). Additionally, in aforementioned Fan & Gruenfeld (1998)'s experimental study, the authors found that when a high level of task interdependence (e.g., resource interdependence) existed, outcome interdependence (e.g., joint reward) showed no effect on performance. The authors explained that high levels of task interdependence increased task complexity and imposed high cognitive demands on project members. Hence, members who fully engage in learning about tasks and coordinating efforts in problem-solving activities have few cognitive resources available to attend to motivational factors, such as joint rewards, which are not directly related to problem-solving. Therefore, the motivation effect of reward interdependence on behaviors and team functioning may be largely weakened in such situations.

Summary

Current research compared students' learning outcomes under different structural interdependence designs. However, little research has examined how students actually begin to work as a team when they are introduced in an interdependence task setting. It is unknown how students behave, interact, and work with each other to process the task, complete each step, and accomplish task goals. Therefore, simply counting frequency of students' team behaviors and comparing learning outcomes under a particular structural interdependence design is not likely to provide much guidance in addressing aforementioned instructional design problems (e.g., training of skills in oral presentation, effective knowledge/information sharing) and "may not fully capture the mechanisms driving the improved performance of highly resource interdependent groups" (Fan & Gruenfeld, 1998). Significant effort is needed to pursue detailed process data and to research team interaction in team problem-solving.

Second, existing research frequently gathers data based on participant perceptions as primary data source (e.g., Allen, Sargent, & Bradley, 2003; Wageman, 1995) rather than directly observing actual behaviors. However, students' self-report of their perception of efforts could contain socially desirable responses (Allen, Sargent, & Bradley, 2003). For instance, a student who engages in social loafing (individuals' tendency to spend less effort when working in teams than when working independently) may not report that he paid less effort in the teamwork. Therefore, Allen et al. (2003) suggested more objective measures of behaviors and effort are needed to cope with "the possible problems associated with common-method variance and socially desirable responding" (p. 734). Team-work takes time to develop and "groups exhibit developmental phases during which members' relationships and collective effectiveness change over time" (Allen, Sargent, & Bradley, 2003, p. 735). Documenting observed changes in members' behaviors while capturing both individual and team behaviors at different points in the team process may offer direct, objective evidence and valuable data to enrich our understanding of the evolution of interdependence.

Finally, little data have been gathered regarding which behaviors play a vital role during collaboration. Instead of searching for other antecedent variables or testing particular structural features, this study focused on understanding the nature of collaborative behaviors when teams were working on a highly interdependent design task and examining how these behaviors change and relate to a team's performance. The study also attempted to reveal individual and team behavior differences when an identical structurally-interdependent task was given as well as to explore key behavioral factors which may be associated with a team's productivity and collaboration effectiveness.

Analysis of behaviors and teamwork process in high task interdependence.

High task interdependence conditions influence students' task behaviors. High outcome interdependence seems to foster members' motivation and team norms to promote effort in participating in teamwork and completing tasks as collective entities. The level of structural interdependence implies a contingent relationship formed in behaviors of different performers in a team (Allen, Sargent, & Bradley, 2003). Historically, student behaviors have been evaluated by counting the frequency and number of target behaviors or interactions. However, Wageman and Baker (1997) identified that "what drives performance on interdependent tasks is the level of *effort* that subjects put into cooperation" (p. 156). Therefore, it is reasonable to argue that investigation of student behaviors in teamwork is about students' observable behaviors and effort they put in their behaviors, actions, and interactions. Although existing instruments lack the ability to provide effective measurement of effort, the construct of effort may be evaluated from direct observations of individuals' behaviors and careful inspection of behavioral differences. For instance, when presenting opinions, person A may simply inform the team about his idea without providing reasoning and explanation, versus person B may demonstrate his ideas with supportive information, detailed explanation, and clear reasoning. It is reasonable to argue that the person B exerted more effort than person A when sharing and exchanging information.

Following this logic, two instruments were developed based on three existing instruments, all of which are process-oriented and have been used to collect behavioral data in complex team problem-solving settings. In the following section, the three selected instruments are introduced. The two newly-developed instruments for this study are described in Chapter 3.

Instrument Development Sources

Three instruments from existing research were the sources for current instrument development. These three instruments included (1) Collaboration Process Rating Scheme (CPRS) by Meier, Spada, and Rummel (2007), (2) Measurement framework for the concept of Joint Problem Space (JPS) by Roschelle and Teasley (1995), and (3) Micro-analytic Map of Interpersonal Dynamics of Collaborative Reasoning created by Kumpulainen and Kaartinen (2003).

Instrument source 1: Collaboration Process Rating Scheme.

The Collaboration Process Rating Scheme (CPRS) instrument was originally created by Meier, Spada, and Rummel (2007) to analyze collaboration process data in their study of students in psychology and medicine who collaborated on solving a complex patient case within a desktop-videoconferencing system. In the Collaboration Process Rating Scheme, Meier, Spada, and Rummel (2007) defined nine qualitative collaboration dimensions used to collect quantitative rating data to evaluate collaboration quality when learners worked together through a desktop-videoconferencing system. These nine dimensions consist of:

1. *sustaining mutual understanding*,
2. *dialogue management*,
3. *information pooling*,
4. *reaching consensus*,
5. *task division*,
6. *time management*,
7. *technical coordination*,
8. *reciprocal interaction*, and
9. *individual task orientation*.

The nine dimensions were grouped under five collaboration processes. These five theoretical collaboration processes include communication, joint information processing, coordination, interpersonal relationship, and motivation. This Collaboration Process Rating Scheme is presented in Table 2-3 below.

Table 2-3

Collaboration Process Rating Scheme (Source: Meier, Spada, & Rummel, 2007)

Process	**Dimensions**
Communication	1) Sustaining mutual understanding 2) Dialogue management
Joint information processing	3) Information pooling 4) Reaching consensus
Coordination	5) Task division 6) Time management 7) Technical coordination
Interpersonal relationship	8) Reciprocal interaction
Motivation	9) Individual task orientation

The construction and implementation of the Collaboration Process Rating Scheme was embedded in a research project, which compared the effects of two instructional supports (model conditions vs. scripted conditions) on computer-supported, collaborative, interdisciplinary problem solving (Meier et al., 2007). Every studied team consisted of two members, one was a medical student and another one was a psychology major. The two students collaborated to solve hypothetical patient cases that required the combined application of knowledge from both psychology and medical areas. The task required that the two students had to be interdependent on each other in order to tackle the given cases. During the team meetings, students used the desktop videoconferencing system to see and hear each other. They also relied on shared workspace and text editors in the system to communicate and discuss issues when they were working on joint solutions. The study sample consisted of 40 dyads and the meeting collaboration were videotaped for all dyads. Each tape includes approximately 55 minutes of recorded meeting collaboration. All videos were watched fully by two trained raters. The videos were viewed and rated in a random order.

In the Collaboration Process Rating Scheme, each of the nine dimensions was rated using a scale ranging from -2 (very bad) to +2 (very good). Raters were also encouraged to take observation notes in order to help readers' understanding of the rating, as well as help raters retrieve their memory to recall why specific scores were given to certain situations. According to the authors, all sampled videos were rated by two researchers. The inter-rater reliability was calculated by the intra-class correlation (ICC, adjusted, single measure) for each dimension of sampled dyads in the study.

As suggested by the authors, Collaboration Process Rating Scheme can be applied to interaction instances in diverse CSCL settings. Compared with the workload required in the analysis of conversation transcripts or other written documents, the rating scheme is more time efficient.

In summary, the nine dimensions in the Collaboration Process Rating Scheme covers major aspects of the collaboration process and are used to collect information that describes the dynamics of member interaction. Therefore, with some adjustment, the nine dimensions in the instrument were helpful in collecting process data including individual and team behaviors and evaluating the emergence and development of behavioral interdependence through direct observation of behaviors in this study. The Interdependence Rating and Observation Scheme, created for this study, was created primarily based on the nine dimensions.

Instrument source 2: Joint Problem Space (JPS).

The concept of joint problem space was first introduced by Roschelle and Teasley (1995). The original framework was used to describe the collaboration process during problem solving in Roschelle and Teasley's (1995) study of two students collaborating on an activity that involved a computer-supported direct-manipulation graphical simulation of the concepts of velocity and acceleration. The Joint Problem Space (JPS) refers to a shared knowledge structure to support problem-solving activities and is composed of (a) goals of the collaborative problem solving, (b) introduction or narratives of the current problem state, (c) recognizing potentially available actions for solving the problem, and (d) associations among goals, problem states, and actions. The Joint Problem Space (JPS) defines the foundation of group cognition (Cakir, Zemel, & Stahl, 2009). Establishing and maintaining a Joint Problem Space is the fundamental activity in which students engage in during collaborative problem solving (Roschelle and Teasley, 1995). In order to construct and maintain the JPS, collaborators usually engage in three primary collaborative learning activities: (1) *participation* in social activity; (2) *negotiation* of shared meanings and tasks; and (3) internalizing scientific *representations* and operations (the scientific representations are understood as the eventual products from the negotiation process).

Participation, negotiation, and internalized representation and operations are not separately implemented in collaboration; rather, they are mutually constitutive aspects of knowing.

Guided by the theoretical framework described above, Roschelle and Teasley (1995) suggested five process dimensions in actual data collection and analysis for the purpose of describing the collaboration process at a micro-analysis level. These five dimensions contain *turn-taking*, *socially-distributed productions*, *repair*, *narrations,* and *language and action*. Turning-taking is the most pervasive category in the five dimensions. The following paragraph briefly introduces each dimension.

Specific forms of *turn-taking* (e.g., questioning, acceptance, or disagreement) contribute to different aspects of joint problem solving activities. Turn-taking sequence patterns are indicators of the degree to which collaborative learners participate and contribute to shared meaning-making in problem solving (Roschelle & Teasley, 1995). *Socially-distributed production* (SDP) is a specific form of turn-taking. It refers to the discourse in which learners take turns to complete a sentence (this is called collaborative completion by Roschelle and Teasley). A typical example is IF-THEN sentence, in which the preceding and succeeding are produced on separate turns by different persons during a discussion where collaborators accept an idea in subsequent turns. *Repairs* are the method by which discourse participants tackle problems or discrepancies in collaborative communication (e.g., speaking, hearing, or comprehension of dialog) (Schegloff, Jefferson, & Sacks, 1977). *Narrations* are a verbal strategy (i.e., description, explanation, elaboration, confirmation) that enables partners to explain participants’ own or his/her peers’ actions (Roschelle & Teasley, 1995). *Language and action* in collaboration usually complement each other and serve together as presentations of individuals’ own ideas or acceptance of the partners’ perspectives.

Pros and cons: Joint Problem Solving (JPS) implies *interdependence* in collaboration processes. Interdependence is embodied in the five process dimensions of the JPS. The five dimensions underline the interdependent relationship among the individual collaborators, and also imply the coherent coordination between language and actions of each individual participant or between participating collaborators. Therefore, JPS can be applied to research in collaborative learning circumstances.

JPS was suggested within a face-to-face collaborative learning context in which the student dyad was directly operating a computer-based graphical simulation to help them understand two physics concepts of velocity and acceleration. Different from face-to-face interaction, the interaction in CSCL environments heavily relied on the fluency of the communication supported by synchronous technologies and applications. Transmission delays are common in videoconferencing communication (Meier et al., 2007). In CSCL, collaborators use multiple communication channels to maintain their interaction. For instance, they type in chat boxes to explain their actions in a whiteboard, or use a whiteboard to jot down ideas that were suggested and verbalized by their partners. Actions or language in any single channel may not be coherent or complete. However, taking all actions together in the chat, whiteboard, sharing applications, and utterances, cross-references, and coherence in team communication are required in order to keep the collaboration flow (Meier et al., 2007). Comparatively, the concept of collaboration flow may be more flexible and comprehensive than turn-taking to evaluate conversation transition in computer-supported collaborative environments. According to Meier, et al. (2007), collaboration flow implies “a coherent sequence of messages, both verbally and conveyed through actions, which build upon one another and thus enable the exchange and integration of knowledge and ideas in the collaborative problem solving process” (p. 377).

As a summary, the Joint Problem Space (JPS) and the five process dimensions were helpful to this study because JPS focuses on data regarding interaction in the collaboration process and emphasizes members' interdependent relationship during the collaborative communication and problem-solving. The dimensions of *turn-taking*, *repairs*, and *narration* were adapted, with adjustment, in the Interdependence Rating and Observation Scheme for this study. The adapted dimensions helped collect detailed behavior and interaction data during the collaboration process and supported a microanalysis of members' interdependent behaviors and strategies used in communication, conflict management, and information sharing. The dimension of *language and action* suggested that information demonstrated in members' conversations and actions complement each and serve together for communication purposes. Taking together the information delivered in both language and action guided data collection and analysis processes while maintaining a focus on integration of information delivered in the two channels.

Instrument source 3: Micro-analytic Map of Interpersonal Dynamics of Collaborative Reasoning.

The Micro-analytic Map of Interpersonal Dynamics of Collaborative Reasoning was created by Kumpulainen and Kaartinen (2003) and was used to depict sequential organization of peer interaction in joint problem-solving.

Kumpulainen and Kaartinen (2003) suggested that mutual participation and engagement are required for peer collaborators to succeed in joint negotiation and development of shared understanding regarding the given problem. The purpose of their study was to investigate the collaborative reasoning sequences in heterogeneous peer collaboration when the collaboration dyads worked together to perform an open-design task in elementary geometry. The two authors looked specifically at students' social interaction/communication processes, collaboration sequences, mathematical problem solving, and how student collaborators performed their collaborative problem solving through sequences of reasoning activities.

The authors suggested four constructs to fulfill their research purposes: C*ommunicative Functions*, *Social Activity*, *Problem-solving Strategies*, and *Use of Mathematical Language*. The first two categories were introduced here due to their relevance to this study. The present study focused on members' behaviors in communication, planning, and decision-making, rather than simply understanding what specific (engineering) strategies were used and what particular engineering knowledge was applied in solving the design project.

Communicative Functions: the communicative functions were defined for every utterance with regard to their *retrospective* and *prospective effects* on team conversations in both content and form. Twelve communicative functions were suggested in their study, including: *informative*, *argumentative*, *reasoning*, *evaluative*, *organizational*, *interrogative*, *responsive*, *repetitive*, *agrees/disagrees*, *dictation*, *reading aloud*, and *affective* (see Table 2-4). The analysis of communication functions was conducted at an utterance level. Detailed description of these categories is presented in Appendix D.

Table 2-4.

Communicative Functions (Source: Kumpulainen & Kaartinen, 2003)

Communicative Functions	**Description**
Informative	Provides information
Argumentative	Justifies information, opinions, or actions
Reasoning	Provides reasons
Evaluative	Evaluates work or actions
Organizational	Organizes or controls behaviors
Interrogative	Poses questions
Responsive	Replies to questions
Repetitive	Repeats spoken language
Agrees/Disagrees	Expresses agreement/disagreements
Dictation	Dictates text
Reading aloud	Reads text aloud
Affective	Expresses feelings and emotion

Analysis of Social Activity: the analysis of the students' social activity featured the nature of collaboration. Kumpulainen and Kaartinen (2003) suggested six Modes of Social Activity, including: *confusion, dominative, conflict, argumentative, tutoring,* and *collaborative* (see Table 2-5). The analysis of social activity was performed at an episodic level using the six modes.

Table 2-5.

Social Activity Categories ((Source: Kumpulainen & Kaartinen, 2003)

Category	**Description**
Collaborative	Joint activity characterized by equal participation and shared meaning making
Tutoring	Student helping and assisting another student
Argumentative	Students are faced with social or cognitive conflicts that are resolved by rational argumentation and demonstration
Conflict	Students are faced with cognitive and social conflicts that are left unresolved
Domination	Student dominating the work, which leads to unequal participation in joint reasoning
Confusing	Characterized by the lack of shared understanding

When analyzing a conversation, the authors first categorized every utterance by Communicative Functions. When they finished communicative categorization at the utterance level, they reviewed the conversation and divided the conversation into small episodes by Social Activity Mode. Then, they laid the communicative functions and social activity modes together by using the Micro-analytic Map to analyze a team's strategies or activities for specific social activity purposes. See Figure 2-2 for an example scanned from the original paper.

TABLE 7. The Nature of Social Interaction in Case Dyad 1

Session: 1.1.2 Mathematics
Pupils: Sami and Teemu
Working time: 9:09–9:23

Time	Participation: No.	Participation: Student	Transcribed peer interaction	Communicative functions	Social activity	Contextual notes
9:18	125	Teemu	"Bottom.... How come?"	Argumentative Question	Collaborative	
9:19	126	Sami	"No … but that's the bottom … that's that sort of a triangle and the lid is that sort of a triangle … they are connected … it shows there how they are connected."	Answering by demonstration	Collaborative Tutoring	
	127	Teemu	"No … look … this is...."	Argumentative		
	128	Sami	"Yeah … it's connected."	Argumentative		
	129	Teemu	"Wait."	Organizing		
	130	Sami	"That could be created by side triangles in a way."	Reasoning		
	131	Teemu	"A triangle comes here … a triangle comes here … a triangle comes here and here comes a rectangle."	Reasoning by demonstration		Outlining the geometrical object

Figure 2-2. An example of using the original Micro-analytic Map (scanned copy) (Source: Kumpulainen & Kaartinen (2003)

Pros and cons: the Communicative Functions and Social Activities Modes for analyzing collaborative reasoning were meaningful because of their emphasis on collaborators' joint efforts toward problem-solving. The authors itemized 12 communicative functions and six social activity modes in order to maximize their capture of students' collaborative reasoning process.

However, the authors did not explain why these specific functions or modes were selected. No systematic theory was introduced to support the six social activity modes; therefore the organization of the six social activity modes was somewhat confusing. For instance, the authors stated that "the argumentative and tutoring modes of interaction characterize the nature of the collaboration between the participants; in this sense, they can be regarded as submode of collaborative activity" (P. 340). However, in the actual six social activity modes, argumentative and tutoring modes paralleled with collaborative mode. Conceptually, it is confusing (1) whether argumentative or tutoring activities should be part of collaboration and (2) to identify differences between collaborative activity and collaboration.

Regardless of these conceptual issues, the Micro-analytic Map, which contains the Communication Functions and Social Activity Modes, is still insightful due to its advantage of micro-analyzing collaboration conversations at both utterance and episodic levels. A member's one utterance / statement may serve multiple communication functions. Inspecting members' utterances and looking carefully at every utterance's communication functions can be useful to demonstrate members' efforts in teamwork. In the aforementioned example, when presenting opinions, person A may simply inform the team about his idea without providing reasoning and explanation, versus person B may demonstrate his ideas with supportive information, detailed explanation, and clear reasoning. Person A's statement only serves informative function versus person B's presentation of his opinions serves informative, explanative, and reasoning functions. By comparing the two persons' presentation utterance content and the communication functions their presentation utterances serve, it is reasonable to suggest that person B exerted more effort than person A in presenting ideas. According to the authors, every utterance had sequential, close associations (i.e., analysis of the communication functions at the utterance level) with its preceding and following utterances and such associations contributes to certain communication purposes (i.e., analysis of the social activity categories at the episodic level). Therefore, the Micro-analytic Map, especially the use of the Communication Functions, is also helpful to capture detailed individual behavior data in teamwork conversations and examine the formation and development of interdependence from members' conversations by looking at how utterances are inter-connected with each other through their communication functions. The Conversation Analytic Map of this study was therefore based primarily on the Micro-analytic Map.

As a summary, three instruments were selected from existing research to help in gathering the data required to respond to the two research questions proposed for this study. The three instruments were created and used for process-oriented, micro-analysis research in the teamwork study field. In the instruments' original research studies, the Collaboration Process Rating Scheme and the Joint Problem Space were used to rate and gather direct observation information of members' collaborating behaviors. The Micro-analytic Map, including the Communication Functions and Social Activity Modes, was originally used in analyzing collaborative problem-solving and reasoning sequences at both utterance and episodic levels. In this study, research question 1 asked about individual members' actual behaviors and behavior change during their teamwork process. Considering the study samples are recorded meeting collaboration videos; the Collaboration Process Rating, the Joint Problem Space, and the Communication Functions in the Micro-analytic Map were most suitable to collect direct observation data regarding individual behaviors and analyze members' individual utterances in the meeting conversations. Research question 2 asked about team behaviors and behavior changes. Therefore, the Collaboration Process Rating Scheme, the Joint Problem Space, and the Micro-analytic Map were appropriate to collect direct observation data regarding members' interaction and analyze members' interactive conversations by studying individual utterances, examining inter-utterance associations, and inspecting the communication purposes of an episode of utterances (see a summary in Table 2-6).

Table 2-6

Alignment of Research Questions with Source Instruments.

Research questions	**Data needs**	**Instrument sources**
Research question 1: What individual behaviors are observed in project teams as they were working on an interdependently-structured task?	Direct observation of individual members' behaviors Conversation data at utterance level	The Collaboration Process Rating Scheme & The Joint Problem Space The Communication Functions
Research question 2: What patterns of team behaviors are observed in project teams as students were working on an interdependently-structured task?	Direct observation of members' interactions Conversation data at episodic level	The Collaboration Process Rating Scheme & The Joint Problem Space The Social Activity Modes & The Micro-analytic Map

Summary

This chapter started with an argument that college engineering students are not well prepared for work in authentic situations where fluent communication and collaboration skills are required to be successful in working with peers from various disciplines, in complex task settings. Instructors and instructional designers' insufficient knowledge and understanding of the interdependent nature of collaborative teamwork may be one reason for inadequate design of teamwork activities and support structures. These insufficient designs may lead to poor collaboration experience for students and limited opportunities for students to develop competencies in collaborative skills. Such a gap in engineering student preparation stimulates a call for additional investigations that focus on the collaboration process to better understand its dynamic, interdependent nature.

As the essence of collaboration, interdependence is usually featured in task structures (i.e., structural interdependence) and can emerge from members' actual behaviors (i.e., behavioral interdependence). Although research has reported that high levels of structural interdependence encourage more task-related collaborative behaviors, motivate students' working efforts, and lead to enhanced team performance, the high levels of structural interdependence implies increased task complexity, which may result in process loss and performance deficit. Therefore, simply structuring interdependence in task features does not always predict members' task-related collaborative behaviors. Understanding structural interdependence is not adequate to understanding a team's collaboration processes. Little research has been found to examine how structural interdependence affects behaviors, how members actually behave in high level task interdependence settings, and how and whether high levels of structural interdependence are associated with high levels of behavioral interdependence. Traditionally, perception data and counts of members' target behaviors were widely used to study the collaboration process. However, neither perception data nor counting of behavior frequencies provide fruitful and direct evidence that describes the dynamic nature of behaviors and members' interaction during the collaboration process. Additionally, few instruments are available to gather detailed behaviors or conversation data during collaborations at the micro-analysis level.

The chapter ended by identifying the research gap between a strong need for collecting teamwork process evidence and lack of effective instruments to capture process behavior data. Three source instruments were introduced that provided a framework to study this problem, which includes examining the collaboration process by looking at individual behaviors and inspecting collaborative meeting conversations at micro-analysis level. Adapted from the three source instruments, two new instruments were created to fit the purpose of this study and these two newly-developed instruments will be introduced in Chapter 3, as well as information regarding research design, case selection, data collection, and analysis.

CHAPTER 3 RESEARCH DESIGN AND METHODOLOGY

Problem and Purposes Overview

The purpose of this study was to examine engineering students' actual behaviors when they worked together on an interdependently-structured engineering design project within a distributed computer-supported collaborative learning (CSCL) environment. This study explored the interdependent nature of collaboration and examined student behavioral factors that may play important roles in contributing to team communication, planning, and decision-making. For this purpose, the following research questions were proposed.

Research Questions

Research Question 1: *What individual behaviors are observed in project teams as students were working on an interdependently-structured task?*

RQ 1-1: *How do these behaviors change over time?*

RQ 1-2*: How may these behaviors affect team performance?*

Research Question 2: *What patterns of team behaviors are observed in project teams as students were working on an interdependently-structured task?*

RQ 2-1: *How do individual students' interactions with each other change over time?*

RQ 2-2: *How do the team behavior patterns change over time?*

RQ 2-3: *How may the team behavior patterns affect team performance?*

This chapter covers information about research design, case selection and data source, and unit of analysis; followed by detailed information regarding the instrument development and validation. The chapter ends with a description of data collection and analysis processes.

Research Design

This study employed an instrumental two-case study design with a descriptive approach. Yin (2014) suggested that case study research is a preferred method in situations when (1) the main research questions are “how” or “why” questions, which seek to explain or describe some present circumstance; (2) a researcher has little or no control over behavioral events; and (3) the focus of study is a contemporary phenomenon (p.2). Yin further elaborated that case study research is relevant if the research questions require an extensive and “in-depth” description of some social phenomenon (p. 4). Additionally, in a case study, the boundaries between phenomenon and context may not be clearly evident (p. 16). Based on these criteria, the case study design is appropriate and relevant for this investigation because:

(1) my primary research interest is to examine *how* members actually behave, in communication, planning, and decision-making, in a high level of structural interdependence task setting, *how* behavioral interdependence was formed out of members’ actual behaviors and interaction, and *how* such interdependence, emerging from actual behaviors, may evolve and develop into certain patterns;

(2) I had no control over the videos being recorded and students’ behaviors in the recorded meetings;

(3) the focus of this study was to investigate a contemporary phenomenon. I was interested in examining students’ behaviors rather than testing specific data points;

(4) my research questions about how the interdependence was formed during the team’s collaboration required an extensive and “in-depth” description of the team’s interaction and collaboration in the CED course context, which was structured interdependently; and

(5) the examination of students' interdependent behaviors likely involved important contextual conditions related to the cases. These contextual conditions can be tasks designed for, or instruction provided to students.

The description of students' behaviors in collaboration may reveal some potential explanations for the different performance between Alpha and Gamma teams; however, the main purpose of this study by using the two cases was to provide a rich description of students' actual behaviors and to understand how interdependence is formed and developed in students' behaviors during their collaboration processes. This fits in the instrumental case study category suggested by Stake (1995). According to Stake, in the instrumental case study, the case serves to help understand phenomena within it; therefore the case and case contexts are of little interest. Instrumental case study researchers use a particular case as the instrument to serve the need for general understanding of the research question rather than to understand the case.

Additionally, the study's findings may help to validate and expand Social Interdependence Theory. As Yin (2014) suggested, the goal of doing case study is for analytic generalization. Analytic generalization means that the cases should be taken as "the opportunity to shed empirical light about some theoretical concepts or principles" (Yin, 2014, p. 40) and the purpose of doing case study research is "to expand and generalize theories" (Yin, 2014, p. 21). According to Yin, analytic generalization could be based on either (a) verifying, modifying, arguing against, or advancing theoretical concepts which were referenced in the study or (b) new concepts that emerged after the completion of a case study. Regardless of generalization derived from either of the sources described above, the generalization is "at a conceptual level higher than that of the specific case" (Yin, 2014, p. 41).

Case Selection and Data Source

Case Selection

This study is a two-case descriptive study. The two cases selected were the Alpha and Gamma teams in the CED course. Four students were in the Gamma team. While the Alpha team initially had four students, one more student joined the team during the middle of the semester so the Alpha team had five students. As described in Chapter 1, participants in both teams were senior engineering students from either of two top research universities located in the northeast United States. Students were either majoring in engineering or mechanical engineering so they shared some fundamental knowledge about engineering. After the Best Practice Sessions, half of the team members were trained in the FEA (Finite Element Analysis) knowledge track and another half of the team members were trained in the AS (Aerospace Structure) knowledge track. Students communicated with each other through the technologies in an AIDE environment (e.g., bulletin board, team's dropbox, team's email accounts). In previous investigations of this project, students were also observed to talk or chat through their personal mobile phones (Wu & Koszalka, 2011).

Yin (2014) suggested that researchers who conduct the case study should "try to aim toward analytic generalizations" and "avoid thinking in such confusing terms as 'the sample of cases' or the 'small sample size of cases'" (p. 42). He further warned that:

> In a like manner, even referring to your case or cases as a 'purposive sample' may raise similar conceptual and terminological problems... use of the 'sample' portion of the term still risks misleading others into thinking that the case comes from some larger universe or population of like cases. (p. 44)

One reason for choosing Alpha and Gamma teams as the study cases was because these two teams were selected in two previous investigations of this course. Using the same student teams can extend and form a more complete understanding of the teams as well as students' behaviors. The two teams were reported to appear different on-task performance in the previous study (Wu & Koszalka, 2011). Prediction of whether the two cases may present similar or different results in other collaboration areas and perform differently in the subject areas was one major focus for this multiple-case study. Second, Yin (2014) suggested replication, not sampling logic, for multiple-case studies. He explained that "each case must be carefully selected so that it either (a) predicts similar results (a literal replication) or (b) predicts contrasting results but for anticipatable reasons (a theoretical replication)" (p. 57). Hence, the replication logic underlying the multi-case study approach is for theoretical interest. If a pattern of results across multiple cases is found, the selected cases would provide significantly meaningful support for the initial propositions (Yin, 2014, p. 58). Social Interdependence Theory suggests that the team with poorer performance may demonstrate less promotive interaction than the team with better performance. Therefore, it is interesting to observe whether students had different performance results in the subject area and whether their behavior differences may be associated with their performance differences. Selecting the two different teams and comparing their performance and behaviors will provide strong evidence to support the theory as well as offer rich description to address the research questions.

Elimination of gender is another reason to use the same two teams in this study. Gender is one factor to explain part of differences in students' collaborative behaviors (Chan, Huang, Hui, Li, & Yu, 2013; Zeng, Duch, Sales-Pardo, Moreira, Radicchi, Ribeiro, Woodruff, & Amaral, 2016). Students in the two selected case teams were all male. Absence of gender differences helps eliminate potential effects that might have been posed by this factor on behavioral interdependence.

Data Source

Recorded meeting video data.

Altogether, one-hundred and forty-two SameTime team meetings were recorded and archived in the AIDE system; however, only eighty-three were retrievable as usable data and forty-seven recordings were done for the Alpha and Gamma teams. Three recorded SameTime meeting videos for each team were selected for this study so six recorded meetings in total. The six recorded meeting videos were selected based on Yin's longitudinal rationale of tracking each team's behavior trends. Yin (2014) defined the longitudinal case study as to study the same case at two or more different time points and suggested that "whatever the time intervals or periods of interest, the processes being studies[d] should nevertheless reflect the theoretical propositions posed by the case study" (p. 53).

In this study, the three videos of each team were selected at three important time intervals and the videos selected in the three time intervals were treated as three embedded units for each team case. A brief introduction of the three time intervals was presented in Chapter 1 and a detailed description of the three time intervals are delineated below in this section. Selection of videos from the three time intervals was based on (1) the temporality reason: the three time intervals happened at the first 60-70% of the course. Data included in the selected video in the three time intervals helped identify teams' initial behavior patterns during the first 30-40% of the course, and provided evidence to evaluate whether teams' initial patterns continued or changed, and (2) the theoretical reason: Johnson & Johnson (2009) suggested that the interdependence among students can vary. Data generated from this study helped track the development and changes of student behaviors longitudinally, at different time intervals.

The first-time interval was the Best Practice Sessions, which were composed of two labs: lab 1 was the moon survival practice and lab 2 was the ball-in-the-pipe practice. As described above, the Best Practice sessions were delivered at the early stage of the semester to help students develop productive teams using the collaboration technologies they newly learnt in the AIDE. During the two Best practice sessions, students were still new to the course and they were learning about the system, the technologies, and their team members. Selection of the Best Practice sessions is based on the temporarity issue in team collaboration as Kapur and his colleagues suggested in their study in 2011. Kapur, Voiklis, & Kinzer (2011) suggested that eventual team performance may be predicted based on what happens in the first 30-40% of a discussion because team discussions tended to settle into fitness plateaus fairly quickly. Kapur’s finding with regard to the temporarity issue in the team collaboration research resonates with the media stickiness theory suggested by Huysman, et al. (2003) and cognitive imprinting theory proposed by Geer and Barnes (2006). Based on the course schedule (Appendix B), the Best Practice Sessions happened at about the first 20% of the course. It was therefore presumed that the Best Practice Sessions in the CED course was the best period to detect teams’ initial communication and interaction behavior patterns. McClintock (1985) suggested that the embedded units can be selected through sampling or cluster techniques (cited in Yin, 2014). Therefore, the lab 1 session was selected randomly for the two teams in the Best Practice Sessions.

The second-time interval was the project planning period. It was a period between the completion of the second lab and the due date for teams to submit their two-page PDR

(Preliminary Design Review) plan (see the course schedule in Appendix B). Basically, this period lasted for about 19 days, starting from September 28th and ending on Oct. 16th. On September 28th, the professor made a presentation to summarize teams' performance in lab 2 practice and identify team collaboration and technology use issues. More importantly, the professor informed each team about planning for their PDR and the due date for the PDR plan, as well as provided detailed guidance on how to do team planning and suggested several important planning strategies and problem-solving steps for students to follow. For instance, the professor suggested that each team could start drafting a level 1 plan by sketching major problem-solving steps (e.g., defining problems, brainstorming, evaluation of alternative solutions) and listing sub-tasks contained in each step. The professor also encouraged the teams to continue from the level 1 plan to a level 2 plan. Level 2 plan was to include more concrete approaches and information such as specific strategies to organize a team's collective efforts for each problem-solving step or sub-tasks and the due dates for each step and sub-task. During the 19 days, each team needed to plan and make their own decisions on things such as drafting meeting schedules and working plan and issues needed to be addressed at each meeting. The planning challenge was beyond simply laying out a team meeting schedule and filling out each time slot with individual availabilities. As described above, team planning required careful consideration of utilizing distributed resources and interdependent knowledge, and making reasonable calculations of time in order to allocate for every problem-solving step. Each team also needed to detail sub-tasks included in each problem-solving step and calculate time required by each sub-task. My initial intention was to select two teams' videos happening at a similar time. For instance, a video for each team happened at the beginning or the end of the planning period so that more comparable information could be obtained when comparing students' behaviors across the two teams.

However, not every meeting was recorded and not every video was usable. Therefore, one video was randomly selected for each of the two teams. Randomization prevents bias that may emerge in the case selection process.

The third time interval was the team project-working on PDR as described in Chapter 1. This period started Oct. 18th and ended Nov. 7th, lasting for 21 days. During the 21 days of project working period, each team concentrated on their preliminary design for the given design problem and also prepared a presentation for their PDR. At the same time, students received training at each DST and were required to master DST knowledge and complete a certain number of assignments. Students faced challenges from their individual knowledge track training and deadlines required in completing PDR for the design project.

Similar to video selection in the second time interval, two videos were going to be selected for each team, at a similar time. However, due to the same issues described in the video selection for the planning period, one video was randomly selected for each of the two teams.

Performance data.

Course performance data are provided by the course instructor and include

(1) The team design project final evaluation results contained team scores of the written report (quantitative), evaluation feedback of the written reports (qualitative), and individual scores (quantitative) based on every member's efforts in and contribution to the CDR written report.

(2) Individual final DST scores were individual assessment scores related to students' individual performance in their DSTs.

(3) The peer-self assessment survey was offered to students twice in the semester. The first peer-self assessment data was collected after PDR was completed and the second set of data was gathered when CDR presentation was completed and students had about one week to complete the survey. The peer-self assessment survey contained ten questions (see Appendix V for the survey). The first five questions were for peer assessment and rest of the five questions were for self-assessment. In general, the peer-self assessment survey collected both quantitative rating data and qualitative commentary information regarding members' understanding of their contribution to the team work and their perspectives on team peers' participation and engagement in the team activity. The instructors provided formative evaluation comments to students after the first peer- / self-assessment data was collected and reviewed. Comparison of the two peer- /self-assessment data provided supplementary information to suggest whether students' behaviors / efforts may continue (or not) from PDR to the end of the course.

As a summary, the course performance data consisted of three parts of data: evaluation of the course final project (the CDR written report), individual DST assessment scores, and peer- / self-assessment information. These data was reorganized as team-level performance data and individual level performance data (see detailed categorization in the following Table 3-1).

Table 3-1

Performance Data Categorization

Performance Data	
Team level performance data	**Individual level performance data**
Course final project evaluation results: evaluation of team CDR written report, containing both quantitative assessment scores and qualitative feedback	- Individual member scores in the team's CDR written report - Individual DST scores - Peer- / Self-assessment data

Other data.

Other data collected for the two teams included team CDR written reports for the design project, course syllabus, class schedules, student rosters, and lecture presentations. These data were used as complementary data to complete understanding regarding the interdependent structure of the course tasks and the instruction being given to students.

Unit of Analysis

Unit of analysis of this study was team (interdependent) behaviors and performance of the Alpha and Gamma teams.

A team's (interdependent) behaviors consist of (1) individual student behaviors and (2) collective interactions or activities built among individual students within each team. Taking a meeting video as an example: each selected video was first reviewed, observed, and rated. Observational notes of individual activities, social interactions in aspects such as information sharing, task management, and team's collective efforts and strategies in problem-solving were documented along with the rating data in order to provide both quantitative and qualitative evidence for an initial evaluation of a team's behavioral interdependence. Then, the video was transcribed into textual information. Each video conversation therefore was the unit of analysis for the conversational analysis. Conversations as the unit of analysis possessed several advantages such as (1) they were objectively identifiable and (2) the unit's parameters were decided by the contributor instead of researchers (Rourke, Anderson, Garrison, & Archer, 2001). Conversation analysis helped generate more detailed quantitative and qualitative data for describing the team's behavioral interdependence, which offered rich complementary evidence to support the ratings and observation data. The conversation analysis data were then synthesized with the observation and rating data to provide a rich description of the team's interdependent behaviors, including what individual and team behaviors displayed, how behaviors evolved, and whether some behavior patterns may form.

As described above, a team's performance data also consist of (1) individual student assessment data and (2) team performance evaluation data. Each team was therefore the unit of analysis for the performance data analysis. The team CDR written report evaluation data were first reviewed to have a general impression regarding how the two teams performed and what performance differences that the two teams appeared to have. Then the performance data was separately by the two teams. Analysis and synthesis of performance data were conducted for each of the teams. Individual members' scores in the CDR written report were first reviewed to obtain individual-level performance differences in the CDR written report. Students' qualitative self- and peer-assessment data were then compared in order to generate high quality of qualitative evidence to address every member's work efforts and contribution to the team CDR written report. These qualitative evidence can explain member score differences in the CDR written report. Further, individual students' DST assessment scores were reviewed and students' performance differences in the subject area were compared. This comparison offered more evidence to explain member performance differences in their team's final CDR written report. At the end, team CDR written report evaluation results, individual DST performance scores, and peer-/self-assessment data were synthesized for the two teams and comparison between the two teams were implemented.

Instrument Development for Behavior Data Collection

As described in Chapter 1, interdependence was examined in three aspects of teamwork process: communication, planning, and decision-making. Two instruments were developed and used for data collection and analysis. The first instrument was the *Interdependence Rating and Observation Scheme*, which was used to collect rating scores and observational notes from observing the selected videos. The second instrument was the *Collaboration Conversation Analysis Categories* and *Micro-analytic Map*, which was used to categorize video conversation transcript data by identifying specific communication, planning, and decision-making behaviors, activities and strategies and analyzing the communicative association between members' utterances. Following is a description of development and verification processes for the two instruments. The description of each instrument is composed of two parts: (1) an introduction of the current instrument and (2) a description of pilot test and presentation of a final version of the current instrument. This section ends with a summary of the two current instruments and their source of validation.

Current 1st Instrument: Interdependence Rating and Observation Scheme

The development of the first instrument, *Interdependence Rating and Observation Scheme*, was largely influenced by Meier, Spada, and Rummel's (2007) Collaboration Process

Rating Scheme and Roschelle and Teasley's (1995) Joint Problem Space Framework. Information regarding these two existing instruments have been detailed in Chapter 2. The first instrument, *Interdependence Rating and Observation Scheme*, contains three parts. Part 1 is *interdependence in team communication* and initially included five sections: (1) collaboration flow: turn-taking, (2) collaboration flow: coordination of language and action, (3) sustaining mutual understanding, (4) repair, and (5) joint participation and mutual engagement.

Part 1 was developed mainly based on Roschelle and Teasley's Joint Problem Space (1995). Development of Part I items was also influenced by Kumpulainen and Kaartinen's study (2003), Meier et al.'s study (2007), and other relevant literature. "Turn-taking," "coordination of language and action," "sustaining mutual understanding," and "repair" were adopted from Roschelle and Teasley's study. However, "collaboration flow" and two sub-categories under the collaboration flow were created and add to make the instrument better fit the AIDE environment (a typical CSCL context) in the current study. "Joint participation and mutual engagement" was also added as one necessary section under Part 1. Kumpulainen and Kaartinen (2003) found that mutual participation necessitated students' collaborative reasoning, including joint practice in performing problem-solving strategies and active interpretation and conceptualization of the tasks. Collaboration seemed to be maintained by collaborators' mutual endeavors to construct shared meaning through explanation and demonstration.

Part 1 primarily focused on evaluating team participants' joint efforts in communication. As it was stated above, keeping the communication flow was the prerequisite to ensure effective collaboration. Items contained in the section of *collaboration flow* included items to evaluate whether team participants maintained mutual attention and whether they had smooth conversation transition turns. When conflicts arose, items in the *Repair* section were used to evaluate whether the team members attempted to or took actions to resolve misunderstandings, reduce conflicts, and get their partners coordinated. The last section, *Joint participation* looks at mutual participation, whether team participants were task-oriented throughout collaborative meeting sessions, and whether students kept the working environment free of distraction.

Both Part 2 "*interdependence in team planning*" and Part 3 "*interdependence in team collaborative decision-making*" were mainly developed from Meier, Spada, and Rummel's Collaboration Process Rating Scheme (2007). Part 2 was developed from the "Coordination" process in the original Rating Scheme. Rating items included in Part 2 primarily focus on assessing a team's joint efforts in team planning and management activities and behaviors. Items included in this part collect rating data and observation information such as whether the team discussed and developed concrete work plans and schedules and how the team coped with time constraints. The last item included in this part was motivation. Motivation was used to assess individual task orientation. According to Meier, Spada, and Rummel (2007), the collaboration process would reflect participants' individual motivation and their commitment to their collaborative work. When individual students oriented to the team task, their collaboration efforts could be observed from their behaviors, such as whether they paid attention to solutions, whether they kept their environment free of distraction, or whether they were observed to nurture a positive expectation and feedback system.

Part 3 was created and expanded from the "Joint information processing" process in the original Rating Scheme. This part specifically targeted examining a team's joint efforts on information sharing, building mutual understanding, and problem solving activities and strategies. Evidence of joint information sharing may have included data such as whether the team members provided explanations for their actions or ideas and whether they asked for information from their partners. Examples of a team's efforts in reaching consensus can be whether the team spent time on critical evaluation of the given information. A definition book was created to address major constructs and variables in the instrument. See Dissertation Instrument Definition Book in Appendix F and the initial 1st instrument in Appendix G.

Pilot test and final version of the 1st instrument.

The purposes of the pilot study were to test instrument validity and reliability and to gather feedback for additional instrument refinement, as necessary. A doctoral student with professional training in education was recruited as the second rater and analyst. The student had taken a couple of research courses and possessed a moderate level of knowledge and skills in research design and data analysis.

Interdependence Rating and Observational Scheme was pilot-tested by using one of the selected videos. The inter-rater reliability between the two raters was .80. Yin (2014) suggested that discussions "are the key part… to test whether the desired level of understanding has been achieved" (P. 82). Disagreements concerning the analysis were discussed between the two raters until mutual agreement established.

Feedback was collected from the second rater in terms of unclear descriptions of codes or concepts. Several changes were made. In the 1st instrument, *Interdependence Rating and Observational Scheme,* several item descriptions were rephrased so that the wording was easy to read and understand. Redundant items were removed. Items that resulted in collecting similar data were synthesized and simplified. The two raters also found that some rating items were not applicable to the CED course so these items were either deleted or modified in order to better fit the current study. As a result, sections included in Part 1 of the instrument "Interdependence in Communication" were reduced from five to three including "collaboration flow: turn-taking", “repair (conflicts)”, and “joint participation” (see the final version of Interdependence Rating and Observation Scheme Sections shown in Table 3-2 below). Sections included in Part 2 of the instrument “Interdependence in Team Planning” were reduced from four to two including: “task management” and “temporal planning” (see the final version of the Interdependence Rating and Observation Scheme Sections shown below). Total rating items were reduced from 41 to 27. The 1st instrument was also reviewed by the faculty in the department. After faculty reviews and pilot testing, the rating scale was changed to: frequently observed (+2), sometimes observed (+1), and not observed / applicable (0).

The final version of the 1st instrument including each rating item is in Appendix H.

Table 3-2

The Final Version of Interdependence Rating and Observation Scheme Sections

Final Version of Interdependence Rating and Observation Scheme Categories	
Categories	**Sections under each category**
Interdependence in team communication	▪ Collaboration flow: turn-taking ▪ Repair (conflicts) ▪ (Joint) participation
Interdependence in team planning	▪ Task management ▪ Temporal planning
Interdependence in team decision-making	▪ Joint information pooling ▪ Reaching consensus

Current 2nd Instrument: Collaboration Conversation Analysis Categories and Micro-analytic Map

The second instrument, *Collaboration Conversation Analysis Categories and Micro-analytic Map*, was created based on the Micro-analytic Map of Interpersonal Dynamics of Collaborative Reasoning. The original instrument was developed by Kumpulainen and Kaartinen (2003).

The second instrument, *Collaboration Conversation Analysis Categories and Micro-analytic Map*, contains three parts. Part 1 is the communicative function categories, Part 2 is Decision/Agreements categories, and Part 3 is the micro-analysis map. Part 1 (Communicative function categories) was developed based on Kumpulainen and Kaartinen's 12 communicative functions for describing and analyzing students' utterances. After reviewing the literature, the original instrument was refined by giving more concrete definitions for each function in order to fit this study. Additionally, one category "*explanative/elaborative*" was added. As stated in chapter 2, explanation and elaboration are important and necessary when demonstrating and clarifying one's ideas to the team. Similar to the analysis approaches done by Kumpulainen and Kaartinen, the analysis of the communicative function categories was at the utterance level in this study.

Part 2 (Decision/Agreement categories) was constructed based on the literature related to convergence (e.g., Kapur, Voiklis, & Kinzer, 2011). Four decision types/categories were created, including decisions/agreements on working strategies, technology-related issues, team management, and content-related problem solving. Similar to the analysis approach in analyzing social activity modes in Kumpulainen and Kaartinen's study, the analysis of decisions/agreements was at the episodic level.

Part 3 is the micro-analytic map. The Current micro-analytic map designed for this study is a table/spreadsheet containing five columns: line number, participants, conversation transcripts, communicative functions, and decisions / agreements (see an example in Table 3-3). The map is used to compile information that resulted from Part 1 and 2. According to Kumpulainen and Kaartinen (2003), the micro-analytic map describes the sequential evolution of collaboration as it documented students' collaborative activities with each other and actions built upon each other's language and/or actions. Different from the original micro-analytic map in Kumpulainen and Kaartinen's study, the current micro-analytic map adapted in this study does not document time points for each utterance in the conversation.

Table 3-3

An Example of Micro-analytic Map for Current Study

Line No.	**Participants**	**Conversation transcripts**	**Communicative functions**	**Decisions / Agreements**
1	BZ	I'd say the portable heating unit cause for the next lowest,	Responsive to the preceding question	
2	BZ	I don't really see how that's going to have that much effect if you go to the cold side of the moon, I'd forget the number, but you know it's some ridiculously low temperature, a plug in heater isn't going to do anything.	Reasoning	
3	BK	Well how long does the night last for? Like if we're going 250 miles or kilometers or whatever, that's going to take a long time, what do we have to be on the dark face of the moon during that do you think?	Interrogative	
4	BZ	That's a really good point and I have no idea.	Responsive to BK's question	
5	BZ	I mean I'd assume that our space suits are fairly well insulated because whether the dark side or the white side, it's either super hot or super cold. I mean even just in between the sun and the shadow, if you get into a shadow it's super cold so maybe I'm giving too much to our space suits but I feel like their insulation is going to be all the protection that we need otherwise we wouldn't even survive five minutes.	Reasoning	
6	BK	I'll buy that.	Agrees	
7	GL	Yeh it is a good point cause you don't ever see like pictures of astronauts like on the moon with like a tote behind heating unit so that' a really valid point, I assume that the space suits are I guess can encompass those temperature variations so in that case that would be pretty useless so we put that at 12,	Reasoning	
8	GL	is everybody okay with that?	Interrogative	
9	MW	Yup that works for me.	Responsive to GL's question	
10	BK	Sounds good.	Responsive to GL's question	Agreement on heating unit ranking

Pilot test and the final version of the 2nd instrument.

The same pilot test procedures were applied for the 2nd instrument. The inter-rater reliability was .77 between the two analysts for coding the communicative functions and was .86 for coding decisions/agreements. Discrepancies, such as coding the same utterance into different communicative functions or having different opinions about decisions/agreements being reached, were discussed between the two raters until the mutual agreement established. Additionally, feedback was collected from the second rater in terms of issues such as unclear description of particular concepts or insufficient examples of particular communicative function. Several changes were made to the 2nd instrument. In Part 1 Communicative Function Categories, five additional categories were added to satisfy data analysis needs: *suggestive*, *confirmative*, *conclusive/summative*, *affirmative,* and *talk aloud*. Part 2 Decision/Agreement categories were also revised. The original four categories were too general to satisfy analysis needs; therefore sub-categories were added under each original category. The final version of the 2nd instrument was presented in Appendix I, J, and K.

Table 3-4 below aligns the two current instruments and data being collected with sources of validations. This table provides a summary review of the development of the two instruments described above.

Table 3-4

Summary of Instruments and Sources of Validation

Constructs	**Instruments**	**Data being collected**	**Sources of Validation**	**Authors**
Interdependent behaviors				
in communication, planning, and decision-making	Interdependence rating and observational scheme	Rating scores; Observation notes	Joint Problem Space Collaborative process rating scheme	Roschelle & Teasley (1995) Meier, Spada, & Rummel (2007)
	Communicative function categories	Categorized conversations at utterance level	Communicative functions	Kumpulainen & Kaartinen (2003)
Decision-making	Decision / Agreement categories	Categorized conversations at episode level	Literature review	e.g., Kapur, Voiklis, & Kinzer (2011)

Data Collection and Data Analysis

Data Collection

As described above, the definition of behavioral interdependence suggests that two levels of data are required for investigating the concept: (1) individual student behaviors during the team activity and (2) a team's collective, interdependent approaches in communication, planning, and decision-making. Motivated by the "Kinds of Data" table in Liptset, Trow, and Coleman's study of the inside politics of an international organization (1956, cited in Yin, 2014, p. 54), a Data Matrix Table (see Table 3-5 below) was created to list the data which were collected for the current study. The data were collected and analyzed at course, team, and individual student levels for each of the case units. The use of multiple data sources results in more convincing and accurate findings or conclusion if these multiple different sources of information follow a similar convergence (Yin, 2014).

The course performance data and other course materials were provided by the course instructor.

Table 3-5

Data Matrix

Kinds of Data			
Behavior Data			
Case units	**Course Level**	**Team Level**	**Individual Student Level**
Team Alpha and Team Gamma	▪ Course lecture presentations ▪ Course documents (e.g., course schedule, DST allocation list) ▪ Course survey data	▪ Meeting observation notes ▪ Meeting features (e.g., duration, attendees) ▪ Meeting documents: data related to team activities (e.g., agenda, documents being discussed in the mtg.) ▪ Conversation transcripts and communication function data at the team level (e.g., the process of reaching a decision) ▪ Meeting interdependence rating scores	▪ Meeting observation notes related to individuals ▪ Individual features (e.g., DST, university) ▪ Meeting documents: data related to individuals (e.g., moderator) ▪ Conversation transcripts and communication function data at individual level
Performance Data			
Team Alpha and Team Gamma		▪ Team CDR written report evaluation data	▪ Individual member scores in the CDR written report ▪ Individual DST scores ▪ Peer- and Self-assessment data

The selected meeting videos for the two teams were analyzed in several phases. In the first phase, the six videos were reviewed and rated using the first instrument, *Interdependence Rating and Observation Scheme*. Due to multiple sections included in the scheme, each video was reviewed multiple times to ensure accuracy and sufficiency of the data being collected. Observational notes were carefully written during several review periods. Observation data complement the rating data by providing additional qualitative information to explain the rating of each item. Documents being shared or discussed during the meeting and other information related to meeting features were also noted during the observation process.

Next, students' conversations in the six selected videos were transcribed into textual information. The written transcripts were first analyzed on an utterance basis by using the *Communicative function categories* in the second instrument. Then, the conversation transcripts were reviewed again on an episodic level for several times to find a team's converging processes toward decisions or agreements by using the *Decision categories* and *Micro-analytic map* in the second instrument. Meanwhile, students' use of different technologies (i.e., audio or chat) in delivering conversations was noted. During some meetings, there were several pauses. The times and durations of these pauses were also recorded in order to calculate the actual meeting duration.

Table 3-6 (next section) aligns research constructs with data, data collection instruments, and data analysis strategies to provide a summary review of the data collection and analysis process of the current study. The table also helps maintain a chain of evidence by linking the research questions with the data, collection instruments, and analysis strategies, and increases the reliability of the information in the case study (Yin, 2014).

The same student helping in the pilot test was recruited as the second rater and analyst for the current study. Baxer and Jack (2008) suggested double coding strategy to ensure the trustworthiness of qualitative data being collected. Double coding is a data analysis strategy "where a set of data are coded, and then after a period of time the researcher returns and codes the same data set and compares the results" (p. 556). In order to increase the trustworthiness of collected data, I did double coding for each of the selected videos when collecting and analyzing the rating, observation, and conversation data before meeting with the co-rater for an inter-rater reliability check.

Baxer and Jack (2008) also suggested that "…the consistency of the findings or 'dependability' of data can be promoted by having multiple researchers independently code a set of data and then meet together to come to consensus on the emerging codes and categories" (p. 556). The co-rater and I worked independently for each selected meeting on (1) rating meeting interdependence, (2) taking observation notes, (3) coding communicative function categories for conversation transcripts at the utterance level, and (4) coding decision categories for conversation transcripts at the episodic level. Inter-rater reliability was calculated for each set of data being coded. Then, the two raters came together to discuss discrepancies until agreements were reached. When coding the communicative function categories for every video conversation transcript, the two raters, respectively, wrote brief explanations next to every utterance to specify why each utterance was coded as a particular communicative function. By doing so, the two raters provided reasonable rationales when they discussed their coding and coding discrepancies.

Addition, triangulation was conducted in this study. Patton (1999) suggested that "…multiple methods of data collection and analysis provide more grist for the research mill…studies that use multiple methods in which different types of data provide cross-data validity checks" (p. 1192). In this study, triangulation of data sources was applied. According to Patton (1999), triangulation of data source is one triangulation method that "comparing and cross-checking the consistency of information derived at different times and by different means within qualitative methods" (p. 1195). Although some quantitative data were gathered, qualitative methods were primarily executed in this study, like observation, conversation analysis, and document analysis. Therefore, in this study, findings in observation and conversation analysis of the sample videos, document analysis of instructors' evaluation feedback, and the analysis of self-reported peer- / self-assessment data were synthesized and triangulated in this study. Consistencies / inconsistencies were noted when emerged in the triangulation process.

Data Analysis

An analytic strategy in a case study usually follows a certain circle or a repeated circle which involves "your original research questions, the data, your defensible handling and interpretation of the data, and your ability to state some findings and draw some conclusions" (Yin, 2014, p. 136). Analyzing and interpreting data for a case study is a continuous process to make a tentative connection between what a researcher thinks may conclude from a study and whether the data provides sufficient evidence to support the conclusion. This section does not delineate all subtle analysis actions taken; rather, it covers two important analysis techniques which guided the final data analysis process: time-series and pattern-matching.

Time-series technique.

A major strength of case studies is to study changes over time (Yin, 2014). The objective of using the time-series analysis technique is for examining "some relevant 'how' and 'why' questions about the relationships of events over time, not merely to observe the time trends alone" (Yin, 2014, p. 154). The time-series was primarily used in this study to answer the research questions related to how certain interdependent behavior patterns may emerge and develop (across the three time intervals) in the CED course when students collaborated in their project work. As Yin (2014) suggested, the essential logic underlying a time-series design is to match the observed trend in the data with a theoretically significant trend presented before the onset of the investigation. The data being examined in this study were compared with theories such as the theory of habitual inertia and promotive interaction suggested in social interdependence theory.

Pattern-matching technique.

Pattern-matching logic is one of the most desirable techniques in case study analysis (Yin, 2014). Pattern-matching technique, specifically in descriptive case study, is to compare the empirical findings with the "predicted pattern of important descriptive conditions defined prior to data collection" (Yin, 2014, p. 143).

To analyze students' behaviors in each of selected SameTime meeting, the pattern-matching technique was applied to compare actual behaviors or behavior patterns emerging from data with the research variables and findings suggested in Chapter 1 and 2 in each of the three aspects (i.e., communication, planning, and decision-making) in the collaboration process.

Table 3-6

Alignment of Research Questions with Data, Data Collection Instruments, and Analysis Strategies

Research questions		**Levels of data**	**Data**	**Data collection instruments**	**Data analysis techniques**	**Data analysis details**
RQ 2: *What patterns of team behaviors are observed in project teams as students were working on an interdependently-structured task?*	Behavior Data	At course level	Course surveys, documents & lecture presentations	Collected from course website	Time-series analysis	To complement primary data from videos and conversations
		At team level & different time intervals	▪ Interdependence rating score	Interdependence Rating and Observation Scheme (Part 1-interdependence in communication Part 2-interdependence in team planning Part 3-interdependence in decision-making)		Rating score comparison across time intervals and teams
			▪ Meeting observation of team behaviors			Observation note synthesis
			▪ Meeting features			Meeting features comparisons between teams and across time intervals
			▪ Meeting documents			Meeting documents were used to complement rating, observation, and conversation analysis data
			▪ Conversation data related to team behaviors	Conversation analysis categories (Part 1-Communicative function categories Part 2-Decision categories Part 3-Micro-analytic map)		▪ Communication function comparisons between teams and across time intervals ▪ Examples collected for interesting communication functions ▪ Examples collected for decision-making processes ▪ Response-to-question/suggestion graph from Social Network Analysis
	Perf. Data	At team level	▪ Team final CDR written report evaluation data	Provided by the instructors		▪ Comparison between the two teams
RQ 1: *What individual behaviors are observed in project teams as students were working on an interdependently-structured task?*	Behavior Data	At individual level	▪ Meeting observation of individual behaviors	Interdependence Rating and Observation Scheme (Part 1, 2, and 3)	Pattern matching	▪ Observation data synthesis
			▪ Individual features			▪ As complementary information
			▪ Meeting documents related to individuals			▪ As complementary information
			▪ Conversation data related to individual behaviors	Conversation analysis categories (Part 1)		▪ Communication function comparisons among individuals within a team ▪ Examples for interesting individual behaviors
	Perf. Data	At individual level	▪ Individual score in the team's final CDR written report	Provided by the instructors		▪ Comparison among members
			▪ Individual DST scores			▪ Comparison among members
			▪ Peer- / self-assessment data			▪ Comparison between the two sets of data

Other data analysis methods.

As described above, quantitative performance evaluation information (including CDR written report scores, individual DST scores) at both team and individual levels were compared to generate team and individual performance differences in the form of quantitative data. Then qualitative performance evaluation data (including CDR written report feedback, peer- / self-assessment results) were synthesized with rating, observation, and conversation analysis results to provide a complete, detailed description of each selected team including how they behaved and how they performed.

Descriptive statistics were applied to analyze the rating information gathered from the Interdependence Rating and Observation Scheme and quantitative data related to communicative function categories and decisions. Social network analysis was used to map the asking-and-responding and suggesting-and-responding interaction patterns of each team. Social network analysis (SNA) is a methodical analysis of social relationships between people, groups, organizations, or other connected knowledge entities. Social network analysis enables researchers to visualize the interaction among people and identify how knowledge and information were shared among them. Social network analysis provides us insight into questions such as where the knowledge and information flow to, who the main contributors and participators are, whether the team participation and engagement are equal, and how the interaction and communication has evolved. NodeXL (Network Overview Discovery Exploration for Excel) was used for social network analysis in this study. NodeXL is a free and open-source software package for network analysis and visualization. NodeXL "builds on the familiar spreadsheet paradigm to provide an easy-to-use tool for nonprogrammers and offers a variety of basic network analysis and visualization features" (Hansen, Shneiderman, & Smith, 2011, p. 54).

Summary

As described, the purpose of this study was to examine engineering students' actual interdependent behaviors (i.e., behavioral interdependence) when they were collaborating on an interdependently-structured engineering design project within a distributed computer-supported collaborative learning environment.

As it has been posited that interdependence is the essence of a collaboration process. Interdependence characterizes the dynamics of teamwork and can impact collaboration outcomes. Since no instrument was available for behavioral interdependence assessment, two instruments were developed based on literature and existing methods.

The first three chapters have established a sound theoretical framework upon which the instruments were built. Two research questions were proposed based on previous finding in the literature and assumptions regarding the potential relationship between a team's interdependent behaviors and collaboration. Chapter 1 clearly defined the problem and provided a solution that this study will address. Chapter 2 delineated a comprehensive review of the literature up-to-date; providing evidence to support the possible relationship as well as presenting gaps in current literature that this study seeks to improve. In this chapter, study design, case selection, data collection, and data analytical procedures and techniques were outlined. The next two chapters will present study findings and discuss implications for future research and practice.

CHAPTER 4 DATA ANALYSIS AND RESULTS

The purpose of this study was to investigate college students' actual collaborative behaviors when they were solving an interdependent engineering design problem in project teams within a distributed computer-supported collaborative learning (CSCL) environment. Two research questions were proposed:

Research Question 1: *What individual behaviors are observed in project teams as they were working on an interdependently-structured task?*

RQ 1-1: *How do these behaviors change over time?*

RQ 1-2*: How may these behaviors affect team performance?*

Research Question 2: *What patterns of group behaviors are observed in project teams as students were working on an interdependently-structured task?*

RQ 2-1: *How do individual students' interactions with each other change over time?*

RQ 2-2: *How do the team behavior patterns change over time?*

RQ 2-3: *How may the team behavior patterns affect team performance?*

The concept of behavioral interdependence was selected for the analysis purpose to capture individual student behaviors, especially those team-like behaviors related to tasks and team performance, and to examine the formation and development of interdependence among participating students during the teamwork process. In order to fulfill this purpose, each team's and team members' individual behaviors were documented, reviewed, and analyzed in three aspects: communication, planning, and decision-making. The behavior pattern was investigated as an individual or a team's recurrent way of acting under a particular circumstance or toward a given object. A longitudinal synthesis and comparison was conducted to observe whether any consistency or change emerged in their behaviors across the three selected meetings.

Additionally, a cross-case analysis was conducted to capture behavior differences between the two teams and explore potential relationships among behaviors, collaboration, and team performance.

This chapter provides a ***task description*** in major course intervals to help readers understand the structural characters designed in each project task and the behaviors which may be expected with designed task structural characters. The chapter continues with ***data analysis and results*** sections. These data analysis results are reported in three sections:

- section 1 reports data analysis and results of team Gamma,
- section 2 reports data analysis and results of team Alpha, and
- section 3 reports the cross-case-analysis results of the two teams.

In response to research questions 1 and 2 regarding behavior and behavior changes, the individual team result sections report individual behaviors, members' interaction, and team behaviors during each team's collaboration process. Potential associations among individual behaviors, members' interaction, and team performance were also explored in these individual team sections. The cross-case analysis result section reveals behavior differences in team collaboration process between the two teams. These behavior difference data help in the exploration of more potential connections among behaviors, collaboration, and performance by comparing key behavior variables of the two teams in response to research questions 1 and 2 regarding how behaviors may affect performance. The chapter concludes with a chapter summary and an introduction to Chapter 5.

Task Description

Task description contains information of related course lectures, tasks' structural interdependence features, and purposes of every selected meeting in its course intervals. A timeline table was first presented for each studied team (see figures 4-1 and 4-2) to align related course lectures and task due dates with the three selected meetings in order to offer readers a clear description of the temporal arrangement of these course elements. As it is seen in these two figures, dates highlighted in bold (Sept 28, Oct 17, Nov 6, Nov 7) were course lectures and assignment due dates designed in the course schedule. Dates highlighted in italics and bold (Gamma: Sept 15, Oct 10, Oct 27 | Alpha: Sept 12, Oct 5, Nov 6) were the three selected meetings.

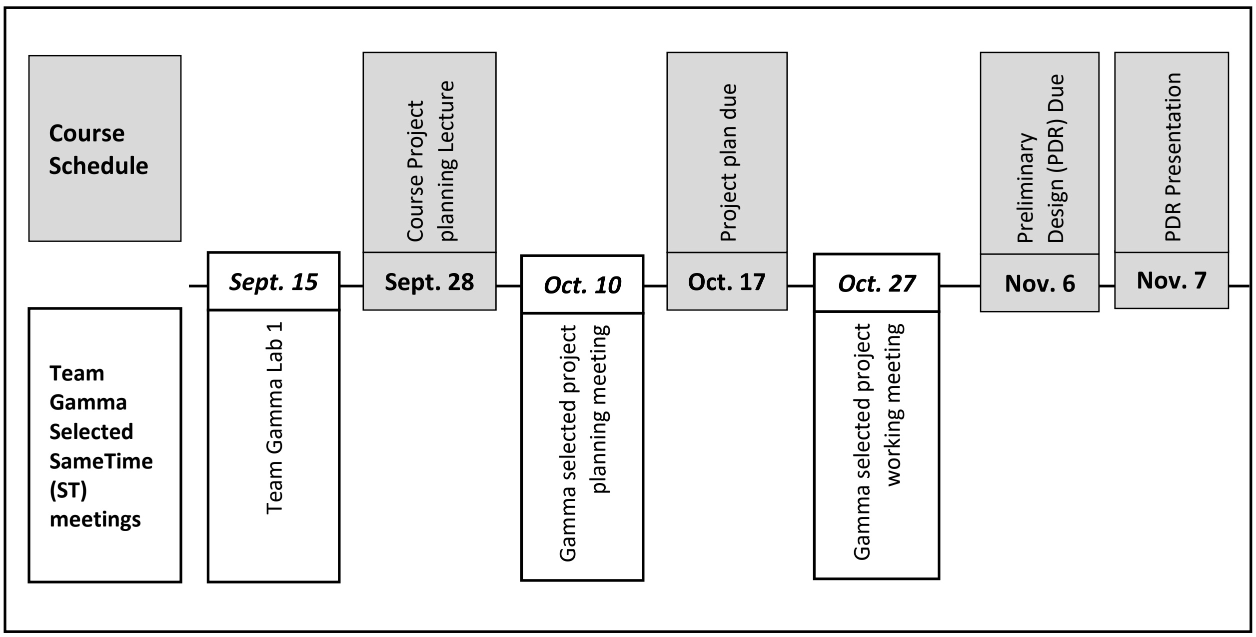

Figure 4-1. Time alignment of course schedule and Gamma's selected SameTime (ST) meetings.

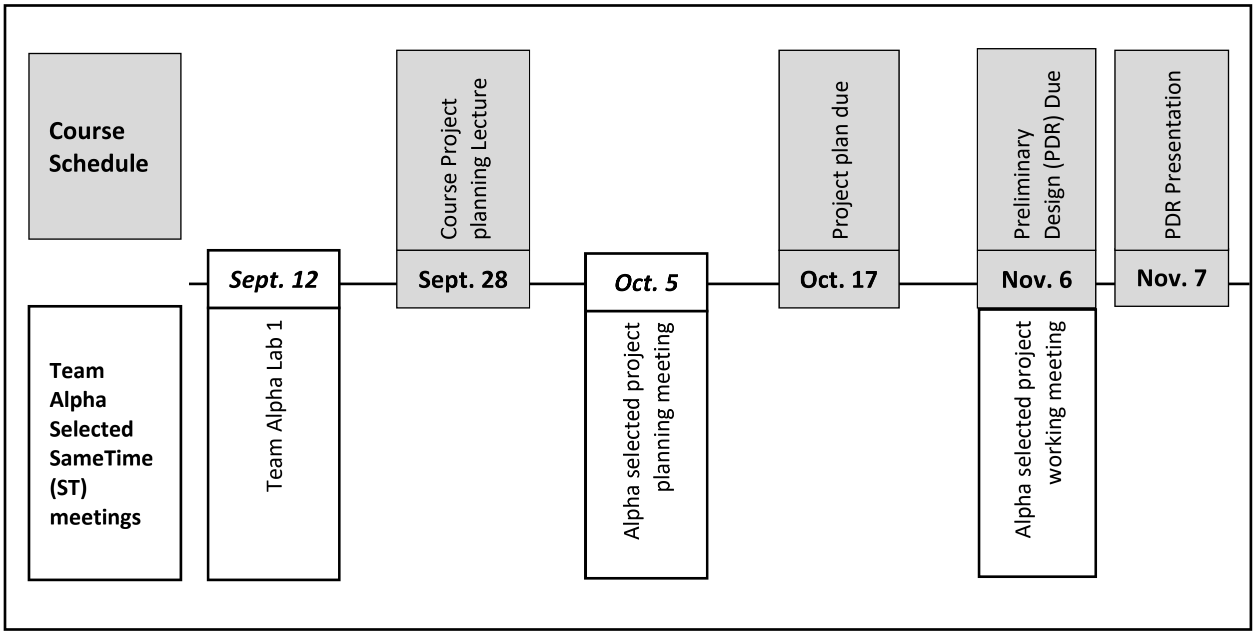

Figure 4-2. Time alignment of course schedule and Alpha's selected SameTime (ST) meetings.

Tasks designed in every course interval possessed several interdependence features. As described above, Best Practice session labs were designed for students to learn about the AIDE system and the SameTime meeting environment as well as to practice team-building skills. In other words, the lab sessions were to get students ready (e.g., getting familiar with the team and practicing tools in the AIDE environment) to work on the engineering design project for which the course was designed. The lab tasks required students' mutual efforts to solve the given lab problems as a team. For instance, lab 1 task was called "Survival on the moon". The task required students to rank the 15 given items in order to survive on the moon given a scenario that the team's spaceship crashed and needed to find the rendezvous point which was about 250 miles away from the crash site (a detailed task description is available for review in Appendix N). Students were required to work out item rankings as a team and to provide rationales to explain the top five items on the team ranking. The *goal* and *reward interdependences* were designed in lab tasks, meaning that students were graded based on their team performance. Meanwhile, students had not split into different DSTs and had not received training in either of the DSTs during the Best Practice lab sessions. Completion of the lab task did not require complementary knowledge and resources but students' basic knowledge in aerospace engineering and mechanical engineering and mutual efforts to negotiate final solutions of the given lab tasks.

As described above, the project planning phase went from Sept. 28th to Oct. 16th. The due date for the project plan was Oct. 17th. For each of the two studied teams, one SameTime project planning meeting was randomly selected from the recorded meetings during this period. At the beginning of this period, a project planning lecture (on Sept. 28th) was delivered. In this lecture, students were provided with general information in topics of project planning, team management, and engineering problem-solving. The instructors required two levels of project planning plans: level 1 plan and level 2 plan. Level 1 plan identified major problem-solving steps for a design project. The instructor recommended six general engineering problem-solving steps which included: (1) identify the problem, (2) define the problem, (3) brainstorm, (4) evaluate potential solutions, (5) implement the most promising approach(es), and (6) evaluate the results. The instructors suggested teams to draft their design plan based on these six problem-solving steps. Level 2 plan was to detail tasks under each problem-solving step and to specify due dates, major deliverables, task allocation, and individual responsibilities. In addition, the instructor emphasized the importance of *mutual participation* and informed students that part of their grade was based on the team performance and individual contribution.

In this project planning lecture, information about the design project was also provided to students. Additionally, as observed in the course schedule (see course schedule in Appendix B), students had been trained in each of the DSTs for about 4 sessions to this point. Students had obtained some basic ideas and knowledge of each DST. Completion of the project planning depended on students' *open discussion* of the project plan, *sharing* and understanding of each DST knowledge (due to resource interdependence), and *collective efforts* in team scheduling through coordinating individual schedules.

The phase of the project working toward teams' preliminary design was from Oct. 18th to Nov. 6th. The team preliminary design was due on Nov. 6th, and the course preliminary design review (PDR) presentation was scheduled on Nov. 7th. For each of the two studied teams, one SameTime project working meeting was randomly selected from the recorded meetings during this period. As observed in the course schedule (see course schedule in Appendix B), students' training in each of the DSTs had continued for about 5 sessions. Students at each DST had obtained a certain amount of knowledge and skills through attending DST lectures and completing assignments. During this period, completion of teams' preliminary design heavily depended on students' collective efforts on: *sharing* and understanding each DST knowledge, *openly discussing* and *reaching mutual agreement* on design issues, completing individual tasks (e.g., calculation, data analysis, research on a particular issue) and establishing *clear*, *mutual understanding* of individual work, *synthesizing* individual work into the team's preliminary design solutions, and evaluation and negotiation of final preliminary design solution from multiple alternatives.

Data Analysis and Results

Section 1 (Case 1): Team Gamma Case Analysis and Results

Team Gamma collaboration overview.

Performance summary.

Team Gamma performance data is summarized in three parts: individual DST scores, CDR written report scores, and individual course final scores (Table 4-1). The CDR written report evaluation data is separated at individual level scores and team level scores. Except for MW, rest of the Gamma team performed well at the individual level. GL, BK, and BZ all achieved high scores in individual DST and were major contributors in the CDR written report. As a result, they received high course final scores. The team was scored 92.3 out of 100 in the CDR written report.

The instructors evaluated team Gamma's final CDR written report excellent and summarized major strengths of the team's CDR report including: very-balanced report, distinguished efforts, highly accurate analysis, optimized design, excellent documentation, and attention to details. The single weakness that the instructor suggested was to increase investigation of alternative design concepts.

Table 4-1

Team Gamma Individual and Team Performance Data Summary

	Members	**DST scores**	**CDR written report scores**	**Course final score**
Team Gamma	GL	96	98	97.2
	MW	79	75	85.5
	BK	96	98	97.0
	BZ	97	98	97.3
	Team		**92.3**	

Both peer assessment data and faculty feedback to the peer assessment information confirmed MW's insufficient participation and fair contribution to the team design project. One of the peer assessment questions asked members to assign monetary reward to peers based on members' perception of peers' efforts and contribution to the team. Based on this information, Gamma members viewed MW's contribution to the team decreased from 10% in the third phase (the PDR phase) to about 7% to the end of the course (Table 4-2).

Table 4-2

Team Gamma Peer Assessment of Individual Contribution to the Team

Members	**Peer Assessment 1 Individual contribution%**	**Peer Assessment 2 Individual contribution %**
GL	31%	34%
MW	*10%*	*7%*
BK	30%	27%
BZ	29%	31%

Peers commented that MW contributed minimal efforts to the teamwork, missed meetings, had low quality work, contributed nothing in his DST field and often seemed to take free-ride, and majorly did clerical tasks. Based on peers' comments and faculty observation, the instructors suggested MW to perform tasks in his technical area, in a complete or timely manner, and to take more responsibilities. However, MW did not seem to improve his efforts / behaviors to the end of the semester.

In contrast, BK, GL, and BZ all performed well in individual DSTs and received high course scores as noted above. Faculty members and peers commented that BK, GL, and BZ contributed significant efforts to the teamwork. This may suggest that individual students who performed well in individual technical area tend to have better participation in the teamwork. They tended to have better work attitude, spend more time and efforts working on tasks, keep the team structured, and focus on the right direction. As a result, they were usually observed to produce high quality of work and contribute great to the team. In contrast, individual students with poor performance in his technical area showed poor efforts and participation in the teamwork and tended to take free-ride or simply took clerical tasks.

Meeting profile.

A meeting profile (Table 4-3) was created to summarize basic features of every selected ST (SameTime) meeting for team Gamma. Basic meeting features contain information of: meeting dates, meeting duration, total word counts, meeting purposes, scheduled tasks, and completed tasks. Word counts were the total words the team members communicated in a meeting. Word counts were estimated from counting conversation transcript words in a meeting, including conversations communicated verbally and in chat. As shown in Table 4-3, team Gamma used about 67 minutes and communicated about 5,763 words in completing Lab 1 task, 63 minutes and 7,888 words in the selected project planning meeting, and 82 minutes and 12,441 words in the selected project working meeting on PDR.

Every selected Gamma meeting had different purposes: Lab 1 meeting was to complete Lab 1 task, selected project planning meeting was to modify and upgrade the team's level 1.5 plan to a level 2.0 plan, and selected project working meeting was for the team to (1) compute and analyze alternative preliminary solutions and (2) compare sets of alternative solutions. In response to research question 2 regarding team behavior patterns, team Gamma used either task description (in Lab 1 meeting) or meeting agendas (in selected project planning and working meetings) to organize its meeting conversations and discussions. The team completed all scheduled tasks within the meeting period. Two common tasks were regularly scheduled and completed in the team's three selected meetings: (1) technology normalization (also named meeting normalization or meeting start in meeting agendas[2]) and (2) delegation of responsibilities for routine tasks (see the meeting profile in Table 4-3).

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[2] See screen-captured meeting agendas for Team Gamma meetings on Oct. 10 and Oct. 27 in Appendix L. No meeting agenda was used in the team's Lab 1 meeting; instead, the team used the Lab 1 task description to guide their meeting progress.

Table 4-3

Team Gamma's Meeting Profile

Meeting Date	Duration	Word Counts	Meeting purpose	Scheduled tasks	Completed tasks
Sept. 15 (Lab 1 meeting)	About 67 minutes	5763	To complete the survival on the moon task in Lab 1	▪ Technology normalization ▪ Completing the lab 1 task ▪ Volunteering /delegating responsibilities for routine tasks	All completed
Oct. 10 (selected project planning meeting)	About 63 minutes	7888	To modify and upgrade team's level 1.5 plan to level 2 plan	▪ Meeting start (normalization) ▪ Finish Level 2 plan ▪ Plan to PDR ▪ Others ▪ Plan next meeting	All completed
Oct. 27 (selected project working meeting)	About 82 minutes	12441	To continue working on the team's Preliminary Design	▪ Meeting normalization (audio/visual check) ▪ Preliminaries ▪ Implementing solutions discussion ▪ Address remaining items ▪ Setup next meeting	All completed

Quantitative evaluation results.

In response to research question 2-1 regarding team member interaction change pattern, interdependence rating score was calculated in order to obtain a general impression of interdependence formed in team Gamma students' behaviors in the selected meetings (Table 4-3). The interdependence score was calculated by dividing the total rating score by the full rating score. The total rating score is to multiply the rated score of an item by the number of items being rated. The full rating score is to multiply the maximum score of an item by the number of items being rated. For instance, 23 items were rated in Team Gamma's Lab 1 meeting and the total rating score was 41. The full rating score for this meeting was 46 by timing the maximum score of an item (which is 2) with the number of items being rated (which is 23). Therefore, the interdependence score was 89% by dividing 41 by the full rating score of 46. Overall, team Gamma received high interdependence scores in all three meetings, suggesting that the team communicated and performed interdependently at a high level. The interdependence score increased consistently from 89% to 96% and the team's average behavioral interdependence was about 93.7%. Reasons that certain items were excluded from the rating and observation process were explained in the table 4-4.

Table 4-4

Team Gamma Interdependence Rating Scores

Selected SameTime Meetings	**Interdependence Rating**	**Interdependence Score**	**Items not included** (not applicable or observable)
Sept. 15 (Lab 1 meeting)	41 out of 46	89%	#8: team participants considered the nature of the tasks, individual resources, and fields of expertise when they negotiated about task division #10: a working schedule/agenda was set up (e.g., due dates for each task) #11: team participants checked the team's progress #13: team had contingency plan(s) to cope with time constraints and/or to ensure a timely and orderly solution to the given problem Reasons that these items were excluded in the rating and observation process: the project had not started yet and a few of team activities had not emerged at this point; not observed
Oct. 10 (selected project planning meeting)	50 out of 52	96%	#12: team participants checked each individual's progress Reasons that these items were excluded in the rating and observation process: since the project was still at the project planning stage, no individual responsibilities related to the project were finally decided and little work was done related to the project and the PDR
Oct. 27 (selected project working meeting)	50 out of 52	96%	#15: team participants helped each other when their partners encountered technical confusion or difficulties Reasons that these items were excluded in the rating and observation process: no technical issue was observed in this meeting
Average		**93.7%**	

Then, frequency and frequency ratio were calculated for every communicative conversation function identified in Gamma student meeting conversations. The frequency and frequency ratio allowed me to observe student behaviors in general and identify major activities and behaviors students were engaged in. Frequency ratio of a communicative function was calculated by using the frequency of this communicative function against the total number of communicative functions categorized in a meeting conversation. For instance, 299 communicative functions in total were categorized in team Gamma's Lab 1 meeting and the interrogative function happened 73 times. Therefore, the frequency ratio of the interrogative function in team Gamma's Lab 1 meeting was about 24.4%, by dividing 73 by 299.

In response to research question 2-2 regarding team behavior change patterns, Table 4-5 showed the frequency and frequency ratio of each communicative function across team Gamma's sample meetings. Average frequency ratio was calculated by averaging frequency ratios obtained in the three meetings for every communicative function. According to the average frequency ratio, team Gamma members were most frequently engaged in *responding, interrogating, informing*, *suggesting*, *explaining/elaborating*, *organizing*, and *reasoning*. Additionally, these seven activities consistently stayed as the top activities that the team spent most time on. Team Gamma spent about 84.0% of Lab 1 meeting time and about 81.8% of selected project planning meeting time on these seven activities. In the selected project working meeting, the team's time spent on the seven activities increased to almost 96.6%.

In Table 4-6, frequency ratio changes across three selected meetings were calculated. Data suggested that students showed increased participation in *explaining/elaborating*, *interrogating*, *informing*, *responding*, and *suggesting* and the increase ranges were more than 3%. Students' participation in *read aloud, agrees,* and *organizational* decreased more than 5% from Lab 1 to selected project working meeting. Responding and explaining were the two activities Gamma students frequently participated in and had consistently increasing trends across the three meetings.

Table 4-5

Team Gamma's Communication Function Frequency Distribution and Average Ratio

Comm. Functions	**Frequency _Lab 1**	**Frequency % _Lab 1**	**Frequency _Project Planning**	**Frequency % _ Project Planning**	**Frequency _Project _Working**	**Frequency % _ Project Working**	**Average Frequency %**
Responsive	73	24.4%	69	27.4%	78	27.9%	26.6%
Interrogative	53	17.7%	39	15.5%	61	21.8%	18.3%
Informative	28	9.4%	19	7.5%	36	12.9%	9.9%
Suggestive	14	4.7%	31	12.3%	22	7.9%	8.3%
Explanative /Elaborative	8	2.7%	22	8.7%	28	10.0%	7.1%
Organizational	30	10.0%	19	7.5%	10	3.6%	7.0%
Reasoning	20	6.7%	8	3.2%	11	3.9%	4.6%
Affective	13	4.3%	6	2.4%	18	6.4%	4.4%
Agrees	21	7.0%	10	4.0%	3	1.1%	4.0%
Summative	5	1.7%	10	4.0%	3	1.1%	2.2%
Evaluative	5	1.7%	6	2.4%	5	1.8%	1.9%
Read aloud	16	5.4%	0	0.0%	0	0.0%	1.8%
Confirmative	7	2.3%	6	2.4%	1	0.4%	1.7%
Repetitive	2	0.7%	5	2.0%	1	0.4%	1.0%
Argumentative	4	1.3%	2	0.8%	0	0.0%	0.7%
Affirmative	0	0.0%	0	0.0%	3	1.1%	0.4%
Total	**299**	**100%**	**252**	**100%**	**280**	**100%**	**100%**

Table 4-6

Team Gamma's Communication Function Frequency Distribution and Change

Comm. Functions	**Frequency% _ Lab1**	**Frequency% _ Project Planning**	**Frequency% _ Project Working**	**ΔFrequency % (Lab1-Project Planning)**	**ΔFrequency % (Project Planning-Project Working)**	**ΔFrequency % (Lab1-Project Working)**
Explanative /Elaborative	2.7%	8.7%	10.0%	6.1%	1.3%	**7.3%**
Interrogative	17.7%	15.5%	21.8%	-2.2%	6.3%	**4.1%**
Informative	9.4%	7.5%	12.9%	-1.8%	5.3%	**3.5%**
Responsive	24.4%	27.4%	27.9%	3.0%	0.5%	**3.4%**
Suggestive	4.7%	12.3%	7.9%	7.6%	-4.4%	**3.2%**
Affective	4.3%	2.4%	6.4%	-2.0%	4.0%	2.1%
Affirmative	0.0%	0.0%	1.1%	0.0%	1.1%	1.1%
Evaluative	1.7%	2.4%	1.8%	0.7%	-0.6%	0.1%
Repetitive	0.7%	2.0%	0.4%	1.3%	-1.6%	-0.3%
Summative	1.7%	4.0%	1.1%	2.3%	-2.9%	-0.6%
Argumentative	1.3%	0.8%	0.0%	-0.5%	-0.8%	-1.3%
Confirmative	2.3%	2.4%	0.4%	0.0%	-2.0%	-2.0%
Reasoning	6.7%	3.2%	3.9%	-3.5%	0.8%	-2.8%
Read aloud	5.4%	0.0%	0.0%	-5.4%	0.0%	-5.4%
Agrees	7.0%	4.0%	1.1%	-3.1%	-2.9%	-6.0%
Organizational	10.0%	7.5%	3.6%	-2.5%	-4.0%	-6.5%
Total	**100%**	**100%**	**100%**			

As a summary, in response to research question 2, students in team Gamma were observed to form a high level of interdependence in behaviors when they were working as a team. The team participated most frequently in the behaviors of interrogating, responding, informing, suggesting, explaining/elaborating, reasoning, and organizational. Responding and explaining consistently increased across the three meetings. In following paragraphs, team Gamma students' behaviors and actions in communication, planning, and decision-making were reported in turn. Individual behaviors' association to team behaviors, team collaboration, and performance were also explored.

Communication.

Collaboration flow: turn-taking.

In response to research question 1 regarding individual behaviors related to turn-taking, data suggested that team Gamma had a smooth conversation flow resulted from members' individual behaviors in all the three meetings. When members entered a meeting, they briefly greeted each other, confirmed members' presence, and conducted quick technology normalization to check the fluency of video and audio transitions. Throughout the meeting, students handed over turns by asking specific questions or naming a particular student. The team's conversations were tightly connected and conversations were built upon each other.

Collaboration flow: response rate and responding behaviors.

In response to research question 1 regarding individual behaviors related to responding behaviors, students responded to questions and suggestions in a timely manner and no significant delay was observed. Response rates for answering questions and suggestions were calculated to evaluate the team's responding behaviors. Team's response rates were presented in Table 4-7 and 4-8.

Table 4-7

Team Gamma's Response Rates to Answer Questions

	#Questions	**#direct responses**	**# indirect responses**	**Question-Responding Rate**
Lab 1	53	50	3	100%
Project Planning	61	59	2	100%
Project Working	40	39	1	100%
Total/Average	**154**	**148**	**6**	**100%**

Table 4-8

Team Gamma's Response Rates to Answer Suggestions

	#Suggestions	**#direct responses**	**#No responses**	**Suggestion-Responding Rate**
Lab 1	14	14	0	100%
Project Planning	22	20	2	91%
Project Working	31	31	0	100%
Total/Average	**67**	**65**	**2**	**97%**

In response to research question 1-1 regarding individual behavior changes, team Gamma's response rate to answer questions continued as 100% (Table 4-7). Majority of the questions were responded with direct answers; while a few questions were responded indirectly, meaning no direct answers were provided. For these indirectly-responded questions, the respondent either asked the questioner for clarification or added more questions to complement the questioner's original question. Asking for clarification or adding complementary questions seemed to support the pursuit of a complete and mutual understanding of the questions between the questioners and respondents; therefore the respondents could provide better answers (see some examples of indirectly-responded questions in Table 4-9 below).

In the first example in Table 4-9, BZ asked the team's opinions regarding the completion and meeting dates for the design step of "problem definition". Instead of giving a direct response, GL added more specific questions by asking whether the team should conduct the problem definition and brainstorming in two separate meetings or combine the two steps in one big meeting. GL's complementary questions encouraged students to think carefully regarding their decision of the meeting date for conducting problem definition, which relies on whether the team decided to combine problem definition and brainstorming. In the second example, BK asked the team whether he should find the temperature variation. After hearing BK's question, BZ realized that BK's analysis results may not include the material properties so he asked BK for clarification.

Table 4-9

Examples of Indirectly Responded Questions _Gamma

Line No.	**Participants**	**Conversation transcripts**	**Comm. Functions**
Example 1*: indirectly responded question in the project planning phase*			
1	BZ	Ok when do we want to do the meeting after that to define the problem? When do we want to have that done by?	Interrogative
2	GL	Yeh are we going to try to do the define the problem and brainstorming at the same time or are we going to keep those separate? Like are we going to do two little meetings instead of one larger meeting?	Interrogative
3	BZ	It doesn't matter to me.	Responsive to Question
Example 2*: indirectly responded question in the project working phase*			
4	BK	Do you guys think I should try and find more information about the insulator and see if I can find the temperature variation?	Interrogative
5	BZ	You are saying you didn't change the properties of the insulation, not the, you didn't look at the properties of the titanium lithium? Which material are you talking about?	Interrogative
6	BK	Uhm, I am talking about the insulating material of, I didn't change any material properties for either case though. I don't really, I kind of just used a base line number for the metal portion. I forget where I found it from, so I probably want to, someone else may have looked into it more, I should probably use their values for it too.	Responsive to Q

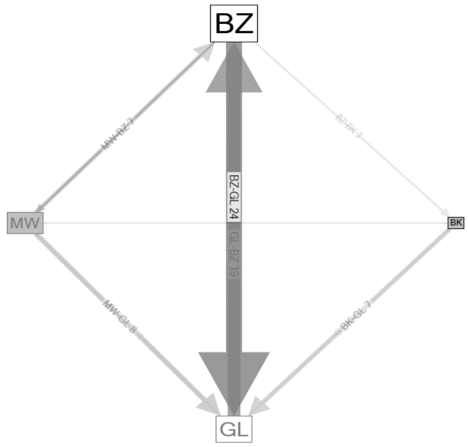
In response to research question 1-1 regarding individual behavior change, the average response rate to answer suggestions is about 97% (Table 4-8). The total 67 suggestions were task-related, such as ideas of better presenting personal ranking in Lab 1 meeting, proposed sub-tasks for every design step in the project planning meeting, and opinions related to the actual design, calculation, analysis, and preparation for the PDR presentation in the selected project working meeting.

In response to research question 2-1 which regards members' interaction change pattern, students' interaction pattern related to their responding behaviors to questions and suggestions in the three selected meetings was mapped out by using social network analysis graphs (see Figure

4-3). Figure 4-3 contains three social network analysis graphs to visualize Gamma members' responding interactions in the three selected meetings.

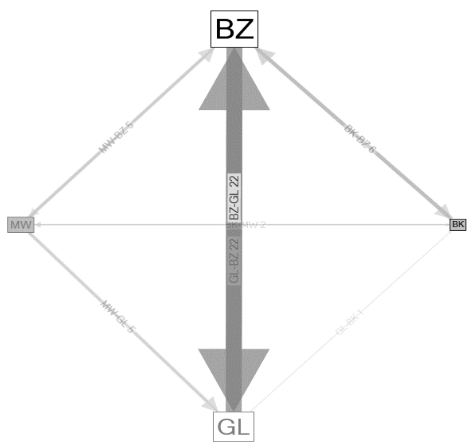
Vertices, the four rectangles at the corners of every graph, refer to each participant. Vertices with the same boundary and label colors are students who were from the same university (GL and MW in gray were from University A; BK and BZ in black were from University B). Vertices with the same filling colors are students who were at the same DST (BK and MW were at FEA track and their vertices filled with gray color; BZ and GL were at AS track and their vertices were transparent). The size of vertices indicated students' participation level in the responsive interaction. If the size is bigger, it means that the student participated more frequently in responsive interaction. Edges with the arrow-shape connected questioners with respondents. The arrow of an edge went from respondents to questioners. The size of an edge indicates the response frequency. When the size of an edge is bigger, the person responded more actively compared to other respondents.

Every social network analysis graph (the left side in the figure table) was companied with edge label description (the right side in the figure table) to display responsive behavior frequency. Responsive behavior frequency counts the number of responses the respondent sent to the questioner. For instance, "BK-GL 7" in Gamma Lab1 meeting means BK responded GL 7 times in the meeting.

<table>
<tr><th>Responsive Interaction
Gamma Lab 1 Meeting</th><th>Edge labels reflecting responsive behavior frequencies</th></tr>
<tr><td>
</td><td>BK-GL 7 BK-MW 1

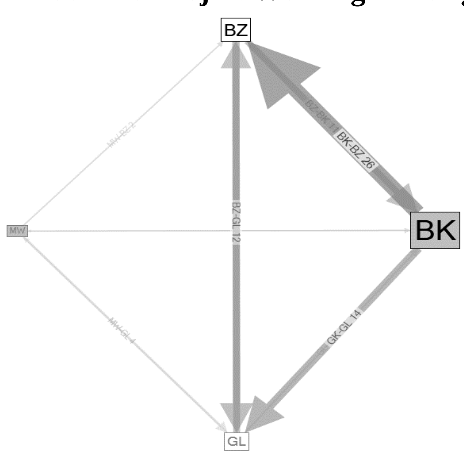
BZ-BK 3 BZ-GL 24 BZ-MW 3

GL-BK 1 GL-BZ 19 GL-MW 1

MW-BK 1 MW-BZ 7 MW-GL 8</td></tr>
<tr><th>Responsive Interaction
Gamma Project Planning Meeting</th><th>Edge labels reflecting responsive behavior frequencies</th></tr>
<tr><td>
</td><td>BK-BZ 6 BK-MW 2

BZ-BK 5 BZ-GL 22 BZ-MW 3

GL-BK 1 GL-BZ 22 GL-MW 1

MW-BK 1 MW-BZ 5 MW-GL 5</td></tr>
<tr><th>Responsive Interaction
Gamma Project Working Meeting</th><th>Edge labels reflecting responsive behavior frequencies</th></tr>
<tr><td>
</td><td>BK-BZ 26 BK-GL 14 BK-MW 1

BZ-BK 11 BZ-GL 12

GL-BK 3 GL-BZ 11 GL-MW 2

MW-BK 2 MW-BZ 2 MW-GL 4</td></tr>
</table>

Figure 4-3. Responsive behaviors to questions and suggestions _ Gamma.

The figures showed that, major response-to-questions / suggestions interaction happened most frequently between GL and BZ (GL responded BZ 19 times and BZ responded GL 24 times) and least frequently between BK and MW (BK responded MW once and MW also responded BK once) in Lab 1 meeting. GL and BZ were the major respondents. A similar interaction pattern was observed in selected project planning meeting. While in selected project working meeting, students' responsive interaction pattern changed. Major response-to-questions / suggestions interaction happened among BK, BZ, and GL. BK seemed taking the primary role in responding to GL and BZ. MW contributed least in responding behaviors. This changed interaction pattern may reflect the emergence of positive behavioral interdependence in the condition of high structural resource interdependence. As described above, solving the course design issue relies on students' complementary knowledge in each DST (i.e., BK was in Finite Element Analysis track, whereas GL and BZ were in Aerospace Structure track). As a team is composed of students from both DSTs, such structured resource interdependence would encourage students to have more communication in knowledge sharing. It is also understandable that more questions related to the actual design practice (e.g., calculation, data analysis) are likely to arise.

Mutual participation.

Overview.

In response to research question 1 regarding individual behaviors related to meeting participation, Gamma students' participation rate and word count ratio, complemented by observation notes and conversation transcript analysis data, were used to evaluate individual students' participation in the meeting.

Students' participation rate was calculated by using a student's participation frequency divided by all members' total participation frequency in a team. A student's participation frequency is the frequency of the student participated in team conversations (both verbally and in chat). All team members' total participation frequency is the sum of participation frequency of all team members in team conversations.

Documenting time points for every spoken sentence is tremendously time-consuming, I therefore used word count (i.e., the total number of words spoken and chatted by an individual student) to estimate the time that a student conversed in a meeting. Every student's word counts were calculated against the total word counts of a meeting to obtain word count percentage (ratio). Students' word count percentage estimates the time a student spent in a meeting compared with the total meeting time and with the time spent by other students. For instance, if student A spoke about 500 words and student B conversed about 1000 words, it is estimated that the time student A spent on the meeting is about half of the time student B spent on the meeting. The following three tables showed individual students' changes in their participation rates and word count ratios (time distribution) across the three selected meetings.

Table 4-10

Students' Participation and Time Distribution _ Gamma Lab 1

Participants	**Frequency**	**Frequency%**	**Word Counts**	**Word Counts%**
BK	34	13.0%	295	5.1%
BZ	100	38.2%	2373	41.2%
GL	81	30.9%	2697	46.8%
MW	47	17.9%	398	6.9%
Total	**262**	**100.0%**	**5763**	**100. 0%**

Table 4-11

Students' Participation and Time Distribution _ Gamma Planning

Participants	Frequency	Frequency%	Word Counts	Word Counts%
BK	18	11.7%	407	5.2%
BZ	58	37.7%	2865	36.3%
GL	55	35.7%	4246	53.8%
MW	23	14.9%	370	4.7%
Total	**154**	**100.0%**	**7888**	**100.0%**

Table 4-12

Students' Participation and Time Distribution _ Gamma Project Working

Participants	Frequency	Frequency%	Word Counts	Word Counts%
BK	56	33.1%	2243	18.0%
BZ	61	36.1%	3593	28.9%
GL	39	23.1%	6294	50.6%
MW	13	7.7%	311	2.5%
Total	**169**	**100.0%**	**12441**	**100.0%**

In response to research question 1-1 regarding individual behavior change, data suggested that team Gamma students' participation had gradually evolved in a more even pattern among BK, BZ, and GL, except for MW, across the three meetings. The numerical data of participation rate and time distribution rate are insufficient to describe students' actual participation behaviors in meetings, observation data provided more informative evidence. In the first two selected meetings, despite their relatively low frequency of participation, BK and MW remained actively-engaged in team discussions. They were observed to comment on ideas and follow the discussion. Especially BK, he came up with creative ideas and shared information that seemed not being known by other members. For instance, when GL asked the team what parachute silk can be used for at moon in Lab 1 meeting, no one provided valuable information except for BK. BK shared his knowledge by responding "I think … for people out in the woods… you could use that to make like a big signal for airplanes that was flying over." His idea was acknowledged by BZ. Another example was when GL proposed to rank the pistols at 14, BK suggested that the pistol could be used to create a self-propulsion device. His suggestion was not adopted by the team as a doable solution but was complimented by BZ. After checking the experts' solution for this task, BK's idea of using pistol to create a self-propulsion device was actually close to the experts' solutions.

In the project working meeting, BK's participation increased significantly. He finished his portion of analysis work ahead of the team's planned progress. By contrast, MW participated least compared to his peers in this meeting. His participation revealed a decreasing trend. In this meeting, he rarely joined the team discussions related to the design issues and analysis. This was probably because MW did not complete his portion of the design project so he did not have much to offer to the team[3]. Despite his low participation rate, MW seemed still following the team conversation.

Although Gamma students' participation in meeting discussion is relatively even, they appear to play different participatory roles. Data presented in Table 4-13 reveals Gamma students' different participation in communication strategies. Data suggested that BZ and GL participated more in majority of the communicative strategies in general and they paid particular attention on asking questions (BZ *N*=60/153, GL *N*=63/153), responding to questions (BZ *N*=77/220, GL *N*=59/220), sharing information (BZ *N*=23/83, GL *N*=34/83), providing suggestions (BZ *N*=35/67, GL *N*=20/67), organizing collaboration (BZ *N*=32/59, GL *N*=24/59), and reasoning (BZ *N*=13/39, GL *N*=18/39). BK participated quite often and increasingly in responding to questions (BK *N*=51/220), sharing information (BK *N*=18/83), and explaining or elaborating (BK *N*=15/58). Interestingly, BK was barely observed to participate in organizational activities. Although MW had least meeting participation, he still often responded to questions (33/220) and sometimes joined in other activities, like asking questions, sharing information, or

[3] As observed, MW informed the team that he did not touch the FEA analysis work yet and asked BK whether there was anything left that he could help with at the end of the project working meeting.

affective conversations. These data highlighted the changing dynamics of students' collaboration modes and implied that students played somehow different participatory roles in their collaborative problem-solving processes. Students' different participatory roles may be related to their personal interests, preferences, unique knowledge, and skills. For instance, BZ seemed particularly skillful at organizing team activities. BK was more involved in content-related design issues and often observed to complete his portion of the design work ahead of scheduled deadline. GL is likely to possess a strong temporal sense. He was often observed to drag the team's attention away from the jokes and keep encouraging the team to plan ahead and to schedule extra time for tasks. GL also liked to ask questions, share information, provide explanation, share responsibilities in team organization, reasoning, and show positive affections on the team's work progress (GL N=15/37). Data further suggest that students' participation may be related to their individual work progress toward the team's design project. As MW did not finish his part of design responsibilities, his participation in the selected project working meeting was minimal.

Table 4-13

Team Gamma Students' Participation in Different Communication Functions

Case 1: Team Gamma	**Lab 1**				**Project planning**				**Project working**				
Comm. Function	**BK**	**BZ**	**GL**	**MW**	**BK**	**BZ**	**GL**	**MW**	**BK**	**BZ**	**GL**	**MW**	**N**
Responsive	9	28	21	15	8	29	22	10	34	20	16	8	220
Interrogative	4	14	31	4	2	17	16	4	13	29	16	3	153
Informative	1	9	16	2	4	3	9	3	13	11	9	3	83
Suggestive	1	11	1	1	5	16	8	2	3	8	11	---	67
Organizational	---	17	12	1	---	8	9	2	---	7	3	---	59
Explanative/ Elaborative	1	3	4	---	3	8	11	---	11	8	9	---	58
Reasoning	1	8	8	3	---	2	5	1	3	3	5	---	39
Affective	1	1	7	4	---	2	2	2	5	6	6	1	37
Agrees	3	8	7	3	1	4	5	---	---	1	2	---	34
Summative	---	2	3	---	---	7	3	---	---	---	3	---	18
Evaluative	---	5	---	---	---	1	4	1	---	4	1	---	16
Read aloud	---	---	16	---	---	---	---	---	---	---	---	---	16
Confirmative	1	4	1	1	---	3	1	2	---	1	---	---	14
Repetitive	---	2	---	---	---	3	2	---	---	1	---	---	8
Argumentative	1	2	1	---	---	---	2	---	---	---	---	---	6
Affirmative	---	---	---	---	---	---	---	---	---	---	1	1	2

Overall, data suggested that students stayed focused on task-related activities across the selected meetings and few distractive behaviors were observed. Analysis of the team's affective conversations further supported this finding (see Table 4-14 below for the affective conversation statistics).

Table 4-14

Affective Conversation Frequency in the Three Selected Meetings _Gamma

	Frequency	**Frequency%**	**Word Counts**	**Word Counts%**
Lab 1	13	4.4%	96	1.7%
Project Planning	6	2.4%	32	0.4%
Project Working	18	6.4%	118	0.9%

Participation in affective conversations.

In response to research question 1-1 regarding individual behavior changes, Gamma students spent a limited amount of time on affective conversations. Among the 13 affective conversations observed in Lab 1 meeting (see Table 4-12), 7 were related to greeting when the students entered the meeting or making farewell to each other when the meeting ended. Other affective conversations were all task-related which included students' comments on the team's or peers' progress, such as "Alright sweet, that worked well" and "Alright cool, so uh here's our wonderfully written ranking". Compared with the affective conversations in Lab 1, the affective conversations observed in the team's project planning meeting were fewer and majorly task-related. When it comes to the selected project working meeting, students seemed participating slightly more often in affective conversations, while the time they spent on affective conversation was still low at 0.9%. The team's affective conversations were primarily commenting on the team's progress or offering verbal acknowledgement of peers' work. By looking at each affective conversation in the project working meeting, it is apparent that the team maintained a high level of motivation and working momentum throughout the meeting and students were pleased with their progress (see affective conversation examples in Table 4-15).

In sum, Gamma students' affective conversations were for greeting, apologizing, providing verbal acknowledgement of peer's work, commenting on the team's progress, and showing appreciation. These affective conversations were necessary to show respect to members, acknowledge each other's work, and keep good working momentum without bringing distraction to the discussion.

Table 4-15

Examples of Affective Conversations _ Gamma

No.	Participants	Conversation transcripts	Comm. Functions
Example 1	BZ	Hey guys,	Affective: greeted
Example 2	GL	So sorry about that.	Affective: apologized for being late
Example 3	GL	Then that's, I mean that sounds, you know, if I were to say in, like I said I had no idea that you were doing this at University B, which is fantastic,	Affective: verbal acknowledgement of the work University B students had done
Example 4	BK	See ya Brian.	Affective: made farewell
Example 5	GL	That's cool. Alright awesome so it looks like we are in pretty good shape. Alright cool.	Affective: commented on the team's progress
Example 6	MW	Thank you.	Affective: showed thanks

As a summary, individual student communication behaviors seemed contributing to the formation of a team's communication behavior pattern. In response to research question 1-2 regarding how individual behaviors may affect team behaviors and/or performance, data suggested that the team was able to maintain its fluent communication through students' individual behaviors such as mutual participation, timely responses to questions and suggestions, ensuring accurate understanding through explicit explanation, and building new knowing through shared knowledge and ideas. Individual members' behaviors of greeting, ensuring member presence, and technology normalization also supported the formation of a habitual entering-meeting behavior norm as a team. Students' such promotive behaviors further contributed to enhanced team collaboration, continuation of these team-like behaviors, and formation of interdependence in students' communication.

Resulting from individual students' promotive behaviors as described above, team Gamma's behaviors in maintaining collaboration flow and participation continued from Lab 1 meeting to the project working meeting. In response to research question 2 regarding team behavior patterns and team behavior changes, team Gamma consistently showed team-like behaviors including: (1) the team stayed focused on tasks and rarely participated in task-unrelated conversations. Few disruptive behaviors were observed during meeting conversations, (2) students' participation evolved more evenly across the three meetings, and (3) the team's response rate stayed high and students' conversations were tightly connected, and (4) students built up and maintained positive interpersonal relationships through behaviors such as showing respect and acknowledgement in task-related affective conversations and their collective efforts in sustaining a positive working momentum.

Planning.

Task planning and management.

Examination of team Gamma students' planning and management behaviors started from reporting the descriptive statistics of the team's organizational conversations (see Table 4-16 and 4-17), followed by activities (e.g., managing routine tasks) and strategies the team used to facilitate task planning and management.

In response to research question 2 regarding individual behaviors, Team Gamma members' participation in organizational conversations decreased from 10% to 7.5% and to 3.6% (Table 4-15). The time spent on the organizational conversations also decreased from 8.0% to 5.3% and to 2.6%. The team's average participation rate of organizational conversations was about 7.2%. Suggested by data shown in Table 4-16, BZ and GL were two major contributors to team organization and BK rarely participated in organizational activities.

Table 4-16

Organizational Communicative Conversations by Meeting _ Gamma

Organizational Communicative Conversation Frequency & Word Counts by meeting				
Selected Meetings	**Frequency**	**Frequency%**	**Word Counts**	**Word Counts%**
Lab 1 meeting	30	10.0%	461	8.0%
Project Planning Meeting	19	7.5%	419	5.3%
Project Working Meeting	10	3.6%	326	2.6%
Total / Average	**59**	**7.2%**	**1206**	**5.3%**

Table 4-17

Organizational Communicative Conversations by Meeting and Participants _ Gamma

Organizational Communicative Conversation Frequency% by meeting and participants			
Participants	**Frequency% _ Lab 1**	**Frequency% _ Project Planning**	**Frequency% _ Project Working**
BZ	56.7%	42.1%	70.0%
GL	40.0%	47.4%	30.0%
MW	3.3%	10.5%	0.0%

Organizational conversations were mainly for managing the team's behaviors or actions. Organizational conversations were important to help team Gamma stay focused on completing scheduled work within the meeting period. At the beginning of the team's project planning meeting (the first example shown in Table 4-18), BZ said "Okay so let's set a meeting as soon as we can so we can identify the needs that we can, and then delegate responsibility for research". BZ's organizational conversations helped the team to focus on their current need of setting a meeting and to realize that they cannot start their problem-solving until the meeting was scheduled. The second example in Table 4-18 also served the same organizational purpose.

Organizational behaviors sometimes include conversations which guided other team members' behaviors. Such organizational behaviors were helpful to keep the conversational flow or ensure the quality of the work. For instance, as the third example showed in Table 4-18, BZ and GL were talking at the same time and interrupted each other. BZ then said "Go ahead" to indicate GL to speak first. In the fourth example shown in Table 4-18. GL tended to confirm that every routine task was done correctly. He said to BK "Brian, make sure you have the chat too as well. I don't know if you save them at the SameTime but I think that is saved as well."

When students said something organizational, they may have suggested future actions, rather than direct the team's or an individual student's immediate actions. These suggestive organizational conversations helped ensure that effective communications would continue even when some team members were not present in a meeting. In the 5th example in Table 4-18, BZ needed to leave the meeting early to attend his class. He asked the team to save the discussion notes in the meeting minutes so he could read the notes without missing anything important. The 6th example served a similar suggestive purpose.

Table 4-18

Examples of Organizational Conversations / Behaviors _ Gamma

No.	**Participants**	**Conversation**	**Organizational Comm. Function**
Example 1	BZ	Okay so let's set a meeting as soon as we can so we can identify the needs that we can, and then delegate responsibility for research	Organizational: organized the team's behaviors by suggesting focusing on the current need
Example 2	BZ	so I think, does anybody have anything that they need to move on, and if not, let's figure out what we want to do now, what our plan is for implementing this.	Organizational: organized the team's behaviors by suggesting what the team should do next
Example 3	BZ	Go ahead Greg.	Organizational: asked GL to speak when the two spoke at the same time
Example 4	GL	Brian, make sure you have the chat too as well. I don't know if you save them at the same time but I think that is saved as well.	Organizational: directed BK's behavior by informing him to save the chat when closing the meeting
Example 5	BZ	If you guys make any sweeping decisions after I leave, whoever takes the minutes, just include those and I will read them over and make sure I didn't miss anything major in that.	Organizational: BZ directed the team's behavior by asking the team to include the discussion during his absence in the meeting minutes
Example 6	GL	if you Brian as far as posting these temperature stuff tomorrow, if for whatever reason just send me an email just to let me know that you have it up there, just so I know and if there is any other issues or clarifications on there	Organizational: directed BK's behavior and reminded BK to send an update email to him

Managing routine tasks.

Routine tasks were scheduled, delegated, and completed in every selected Gamma meeting. Routine tasks included: acting as meeting moderator (including setting up the meeting, saving the meeting, Whiteboard notes, and chats, and closing the meeting), taking course surveys, writing meeting minutes, preparing for meeting agenda, and writing weekly progress report. In response to research question 1 regarding individual behaviors in task management, Gamma students usually rotated or volunteered for routine tasks. At the end of each meeting, students checked the completion of routine tasks and ensure that every routine task was done correctly (see example 4 in Table 4-18 above). Table 4-19 listed routine tasks completed by individual students in the three selected meetings.

Table 4-19

Team Gamma's Routine Tasks Completed by Member and by Meeting

Selected SameTime Meeting	**GL**	**BZ**	**BK**	**MW**
Sept. 15 (Lab 1meeting)	Recorder specifically for this activity: recorded teams' ranking and uploaded the team's final ranking and summary of team's ranking rationale to the team's dropbox Took course individual survey	Meeting moderator: set up the meeting, saved the meeting and Whiteboard notes, and closed the meeting Took course individual survey	Took course individual survey	Took course individual survey
Oct. 10 (selected project planning meeting)	Wrote and posted meeting minutes, updated level 1.5 plan to level 2 plan in the planning document, and prepared two pages of project plan presentation for PDR	Wrote down notes on the Level 1.5 document in the Whiteboard during the team meeting discussion	Meeting moderator: set up the meeting, saved the meeting and Whiteboard notes and chats, and closed the meeting	Meeting moderator for the next meeting: to set up the next ST meeting and agenda
Oct. 27 (selected project working meeting)	Meeting moderator: set up the meeting, saved the meeting and Whiteboard notes, and closed the meeting Meeting moderator for the next meeting: to set up the next ST meeting and agenda	Because BZ left early for his course, no routine tasks were delegated to him in this meeting. Rest of the team members took care of all the routine tasks for this meeting	Wrote and posted the meeting minutes	Took the course team survey and wrote the team's weekly progress report

Actions and strategies helpful to task management.

In response to research question 1 regarding individual behaviors in task planning and management, Gamma students used several strategies to manage tasks, including development of the team's design steps, recapping, and summarization.

Development of the team's seven design steps: Based on the six problem-solving steps suggested in the instructor's course lecture on September 28th, Gamma students developed seven major design steps in its level 2 plan for the design project. Team Gamma's seven major design steps included: (1) identify the problem, (2) define the problem, (3) brainstorming, (4) evaluate potential solutions, (5) implement solutions, (6) evaluate the designs, and (7) final product (see Appendix Q). In its level 2 plan, team Gamma specified tasks under every design step. For instance, in order to complete step 2 "Define the problem", team Gamma students believed that they need to "Very specifically define the objective of the project" by researching into previous, related work (e.g., how to attach panels to CEV) and generating specifications (e.g., FOM[4], definition of safety)". Additionally, team Gamma highlighted three important due dates in the level 2 plan, which included October 7th for PDR plan, November 6th the due date for PDR presentation, and November 7th for PDR presentation. Students also listed detailed task description and expectations for individual members' behaviors and efforts. For instance, by the PDR presentation on November 7th, the team noted that "During lecture we will orally present our PDR. Everyone's attendance is required." By outlining each design step, specifying task details, noting important due dates, and adding task description and team expectations, team Gamma students seemed making great efforts to establish a mutual and clear understanding among them regarding the design project, every design step, and specific tasks they would

[4] FOM stands for Features Of Merits

continue to do. Laying out the important dates in the plan also helped the team stay aware of the time and keep track of their work progress.

Recapping and *summarization:* were observed as two helpful strategies observed from team Gamma's task management activities (see exemplary conversations in Table 4-20 below). Close to the end of the project planning meeting, BZ recapped the meeting and each person's responsibilities for the team's routine tasks. GL then added some complementary notes about the work he planned to work on. BK also asked who would post the minutes to ensure no routine task was missed. Through recapping, students were reminded of their individual responsibilities to ensure no task was missed.

Table 4-20

Using Recapping Strategy in Organizing Meeting Tasks _ Gamma Planning Meeting

Line No.	**Participants**	**Conversation transcripts**
1	BZ	so just to *recap*, Greg you are going to make the changes and update that and send that out and maybe even put that on the power point slides, if you want somebody to handle that or you need some help, just you know, send an email out and we'll figure out who wants to help you. Mike you're going to set up the meeting for the 13th, are you going to do the agenda for that too or should somebody else make the agenda.
2	MW	No I can make the agenda and post it at the same time, it's pretty easy I guess.
3	BZ	Okay so you will make the agenda and uhm, we are all going to study the handout and come in with some general idea of need and their importance and then we'll rank them and agree on them as a group next time. Is everybody on the same page with what we are doing and where we are going?
4	GL	Yup that sounds good. I'll get this new, our level 2 plan out to you guys fairly soon and uhm, certainly before Friday and like I said, I should be okay with the slides cause it is going to basically what we're, you know, our updated level 2 plan on it so I'll be fine with that so I guess other than that, we can all kind of head out.
5	BK	Do we have someone who is going to post the minutes?
6	GL	That's me, I'm posting the minutes for this meeting so we'll have.
7	BK	Okay, just making sure someone had it.
8	GL	Yup that's going to be all taken care of. Oh the other thing too is not, I mean, I'm just remembering it now, we have at the end of every week so we should remember this for Friday's meeting so I guess Mike, when you make the agenda, make sure you put a note in there about someone doing the weekly progress report cause I know we have to do those like every single week. They are not, I did it last week and they are really quite simple to fill out. It's just like a little questionnaire but we need to make sure we do those every week.
9	MW	Yup, note taken, we'll put it in there.

The summative conversation, by definition, refers to summarizing one's or the team's work or previous actions. It was observed to signal the end of one action and imply a move to another action or goal. In response to RQ1-2 regarding how individual behaviors may affect performance, the summative conversations help to remind students of completed actions and to evaluate how much they've accomplished toward the meeting goals, and help students to stay on track. See some examples of summative conversations in Table 4-21 below.

Table 4-21

Examples of Summative Conversations _ Gamma Planning Meeting

No.	**Participants**	**Conversation transcripts**	**Summative Comm. Functions**
Example 1	GL	Alright so we have I guess the, as far as delegating the who does kind of what the brainstorming is kind of all of us I guess, cause like number 3 and 4 is basically individual but then we collaborate again so it doesn't fall on a particular person.	Summative: summarized how the team would approach each project step
Example 2	BZ	Alright so that leaves us with about 5 day buffer to roll over if we need to at all and compile all the slides.	Summative: summarized planned roll-over time
Example 3	BZ	Alright and that leaves me and Greg for closed.	Summative: summarized task allocation
Example 4	BZ	Okay so I think we are pretty close to what we need for almost a level 2 plan at this stage. We got due dates and we've got some rough responsibility assignments	Summative: summarized the team's planning progress
Example 5	BZ	so just to recap, Greg you are going to make the changes and update that and send that out and maybe even put that on the power point slides, if you want somebody to handle that or you need some help, just you know, send an email out and we'll figure out who wants to help you. Mike you're going to set up the meeting for the 13th,	Summative: summarized the sharing of routine tasks

Team Gamma students followed their meeting agendas or task requirements to plan and complete meeting tasks. Team Gamma students usually finished a task then started a new task. When one task was done, there was always one student *summarizing* the team's accomplishment of the completed task to make sure that everyone has the same understanding of the team's progress. When the team started a new task, students usually discussed and decided together about their working strategy. For instance, when team Gamma started their discussion of the ranking items in Lab 1 meeting, the team talked about different strategies and decided to start from the top 5 items, followed by ranking of the bottom five items.

As a summary, team Gamma's task management relies on members' mutual participation, awareness of doing good quality work, and task management behaviors. In response to research question 2 regarding team behaviors, team Gamma's meetings seemed consistently following an organized sequence: every selected meeting began with technology normalization and continued with team discussion of scheduled tasks. Meetings usually ended with the team's delegation of routine tasks. The team developed its seven design steps based on the course instruction. The team followed either the instructor's task requirements or their meeting agendas and used strategies such as recapping and summarization to manage team discussion and problem-solving.

Temporal planning.

As described above, in order to produce high quality work, team Gamma students organized behaviors, regulated routine tasks, used strategies such as recapping and summarization, and finished scheduled tasks in a timely manner. Team Gamma students' temporal planning behaviors also reflected that they made efforts to produce high quality work. In response to research question 1 regarding individual behaviors, Gamma students' temporal planning behaviors were discussed in following paragraphs regarding their: (1) use of a meeting agenda, (2) monitoring individual work and team's design progresses, and (3) formation of time awareness norm.

Use of meeting agenda.

Data suggested that use of an agenda helped the team to organize its design activities and manage task completion within the meeting period. A meeting agenda (called working agenda and minute table) was commonly used in team Gamma's project planning and working meetings. A working agenda and minutes table were usually posted on the first page of team Gamma's whiteboard (a screen-capture agenda of this meeting was attached in Appendix M). The first few lines at the top of the agenda included team name, meeting date, meeting time, meeting location, and meeting attendees. In the center of the table, major tasks planned for the meeting were laid out. Other information included specified leaders for every task, planned completion time, actual time being used, and task outcomes. At the bottom of the table, the agenda contained information such as documents used in the meeting, the student who prepared and posted the meeting minutes, next scheduled meeting time, and the student responsible to post the next agenda. In response to research question 1-2 regarding how individual behaviors affect team performance, students' use of agenda helped them to lay out major tasks, allocate and control the time for each task, check task completion status, and remind about the routine tasks.

In addition, detailed task outcome description for each scheduled task was added in the team's project working meeting agenda (see the screen-captured agenda of this meeting in Appendix M). For instance, the 3rd task listed in the agenda was "Implementing solutions discussion" and the outcome was outlined as "establish the specifics for carrying out our solution for PDR". By adding task outcome details, students could have clearly-written goals to guide their team discussion. In response to research question 1-2 regarding how individual behaviors affect team performance, the task outcome details may further work as quality assurance, which helped the team to evaluate whether their actual discussion outcomes aligned with the expected outcomes.

Monitoring team and individual progresses.

In response to research question 1 regarding individual behaviors in temporal planning, team Gamma students were observed to constantly share their individual work progress and openly discuss about work progress based on individual work status (e.g., GL updated the team about his adhesive findings in the selected project working meeting; BK and BZ updated the team about their progress on the thermal analysis; MW did not complete his individual task and he honestly informed the team). Individual students also informed the team about the tasks they planned to do after meetings and potential dates and time that the individual work would be delivered so that rest of the team and/or collaborative partners had temporal awareness to plan the work (see examples in Table 4-22).

Table 4-22

Examples of Updating Individual Progresses _ Gamma

Participants	Conversation transcripts
***Example 1**: GL summarized his progress, what he was going to do, and when he needed BK's delta T result data*	
BK	That's up to you by like midmorning on Saturday, is that going to be early enough if I give myself like maybe tomorrow morning to finish them off so I can have tonight free?
GL	Yeh, no that's good. Uhm, I still have to do some mechanics with the spread sheets anyways so it is fine, like I don't need the delta T input values like I still have to work out meshing a whole bunch of these independent spread sheets together so there are things that I need to do before that so there's no need to get those delta T's values. So yeh, anytime tomorrow would be fine, you know, afternoon or evening or whatever because after I have it kind of set up then I can kind of take a lot of number crunching but I can work through a lot of this stuff so that's fine. Uhm, but that still is, you still have the, you know.
***Example 2**: BK summarized the work he had done and informed the team, depending on what design the team would design to go, he would need to change his model*	
BK	I've got a base model done, it kind of depends on what kind of base shape we want to do, are we doing the two face sheets, did we decide on that? And like do we want uhm, to kind of have one of the stiffeners right at the edge, or do we want to have it inboard like, if we decide on that kind of stuff we can make the different metals.
***Example 3**: before BZ left, he summarized his work and what he was going to do and when he would do it*	
BZ	I'll see you Sunday then. Just for my own thing, I am going to keep moving forward for the time being, not a lot of work but I am just going to put a little bit of effort into moving forward with my work on the biaxial single face sheet one that I already have pretty much knocked out just because it's such a safe conservative thing for you guys if we decide we are going to go to a sandwich panel whatever, that's fine. I think it is good just to have something to fall back on so that is what I am going to work on this weekend unless you guys think there is something else I could maybe do and if you do just throw that in the minutes.
***Example 4**: GL summarized every person's tasks*	
GL	So, alright then Brian K, Brian Z you can head off, but uhm, I'd say Brian K, you are going to update the, you are going to post that on the AIDE so I will have a delta T for each of the times which will be really good. Uhm, and that I will get the, as a result of that, I will get out the dominant load cases which is good. And then other than that I guess between, you know, Brian and Mike, you guys I would say just maybe start pecking away at the presentation a little bit more.
***Example 5**: MW updated his progress on starting the PDR presentation PPT*	
MW	I kind of took a little stab at it and I posted something up on there on AIDE so if you guys want to take a look and criticism and what not we can just all kind of look at that and take care of it.
BK	Cool, how far into the presentation does that stuff go Mike. Like what subjects did he cover?
MW	Uh, not too far, like the define and all that good stuff in there, like the problem statement sort of kind of. Like I was kind of running like two different directions like presentation wise and like the PDR like report and stuff so I don't know where it fits in between like the two or like right in the middle so I need some help with that but yeh. Some of it's there.

Resource interdependence appears to associate with students' interdependent behaviors in sharing individual progresses. As it is shown in the first example in Table 4-22, GL (at Aerospace Structure track)'s analysis work depended on BK (in Finite Element Analysis track)'s delta T results. Because of the resource interdependence structured in the two DSTs, the work of one team member relied on the progress of his collaborating partners, who are usually trained in a different DST.

In response to research question 1-2 regarding how individual behaviors may affect team performance, students' promotive behaviors in reporting their individual work progress helped them to gauge the team's progress on the design project and plan for timely adjustments when necessary. As it is shown in the example in Table 4-23, BK was suggested to start work on PDR presentation when he finished his portion of the design project (including delta T and thermal analysis) earlier than the scheduled completion time.

Table 4-23

An Example of Adjusting Teamwork Based on Individual Progress _Gamma

Participants	**Conversation transcripts**
GL	if the delta T stuff is taken care of, then I guess do we want to have the FEA guys do something else, or it sounds like you guys are already taking care of a lot of stuff so maybe you don't have anything to do this week which is fine.
BZ	Is there anything that you FEA guys can start doing before we meet Sunday, maybe start a model of the, that you can easily change like the number of stiffeners and the thickness of them; is that too much to start working on now?
BK	That is pretty easy to do…
GL	… So, really I guess …continue to work on the presentation that is something else that can certainly be done. That's not going to hurt because there is a lot of slides that can be taken care of right now.

Formation of time awareness.

In response to research question 1 regarding individual behaviors, data suggested that Gamma students showed strong time awareness during their teamwork process. First, scheduled tasks were regularly completed in a timely manner.

Second, students worked backward to plan their design approaches in the selected project planning meeting; so the team could carefully calculate time needed for every design step. Students also agreed that their project plan should be flexible and more meetings would be added to deal with time constraints and to ensure high quality work.

GL was especially cautious of scheduling sufficient working time for each task. In the selected project planning meeting, GL constantly suggested the team that they should give themselves enough time to prepare the presentation for PDR in order to ensure good quality work (see example 1, 2, and 3 in Table 4-24). In the 3rd example, GL *insisted* that 5 days for preparing presentation was not sufficient and encouraged the team to move the time line a few days earlier so the team could have more time to evaluate solutions and prepare for the PDR presentation.

Table 4-24

Examples of Time Awareness (GL) _ Gamma

Participants	**Conversation transcripts**
Example 1	
GL	I guess we should try to think though to make sure that we do give ourselves that we do *give ourselves enough time* for implementing the solutions so I don't know what is feasible for, I guess we are still doing defining the problem, so I don't know, I guess *can we schedule that sometime earlier* the following week. I don't know if that would work?
Example 2	
GL	This is uh, oh so you are saying just make the I guess the meeting for evaluating solutions just like, cause if we make that meeting on whatever Sunday or something like that, if we make that meeting to evaluate the solutions like within next two or three days, I mean I think *that's probably plenty of time to kind of go over ideas* and then come back in and hit all the stuff again. Because I really think that, I mean we have no idea how many valid design ideas we are going to have but I just know that at least from the closed forms stuff like it's going to take a while to do all these different solutions so *we should definitely try to leave ourselves with a chunk of time to do that.*
Example 3	
GL	Isn't the due date of the PDR on the 6th of November? Doesn't that give us 5 days?
BZ	Oh you're right.
GL	I'm feeling like, in light of that, we need to figure out where we *can cut some days back* here or something. I'm not, well I guess the other thing to consider as well is I think in the preliminary design report, I imagine that you know I think we just need to have designs that would like work. I don't think we need to have like The Design, cause if, you know, we are not trying to finish the complete project by the 6th of November, but so I think as long as we have something that is going in there that is giving us something that is working, that's probably good enough, but I still feel like if due date for implementing solutions is 11/1, then we have 5 days to evaluate the designs and I guess put the presentation together, I *don't know if that is enough time or not.*
BZ	Yeh it is *definitely crunching* it. It might work cause like you said, it is not the final critical design review. I don't think too much iteration has to go on at this stage so it is just kind of going to be looking at the designs we came up with and critiquing them and not necessarily doing too much iteration on them, but you know, 20 slides is going to take a while to make.
MW	Besides just at the very end of this thing, I mean we will be thinking as we go so I am not saying 5 days is enough, but…
BZ	I would probably be comfortable leaving it the way it is as long as we know going into it that kind of the slides we are something we are making along the way and during this following days it is going to more compiling things and less generating them.

Participants	Conversation transcripts
GL	Yeh, I mean I would say because the only thing we probably want to avoid happening is that you know given the ideas we have, you know, until we really implement the solutions we have no idea if they are actually going to work so kind of a little bit iterative at that point. I mean, I guess if we have all of the potential solutions or the solutions we wanted to kind of go with and explore, I guess if we have that done by the 1st it gives us, yeh I mean, *not a whole lot of time*, cause I mean if all of our designs just pretty much just fail, I am not sure whether in this preliminary design report they are looking for successful solutions or whether they just want us to like establish the process of you know, how we are doing this and here are some designs. I really don't know. I just feel like *5 days is not a huge amount of time to go back* and say, "Oh that didn't work, now we kind of have to do it again," or something.
BZ	Okay well what if we did this, what if we gave ourselves a week to implementing and then like say we said the implementing was due on 29th and then that gave us till, then we said uhm, on Nov. 1, the evaluating was, the evaluation stage has to be done which means we will have done some designs, done some evaluating and I think basically we just need a couple of designs that look like they are close to working, all the numbers haven't been crunched and everything hasn't been considered yet, but they are at least reasonable like there is no gross super low safety factors and you know things along those lines like it is impossible to attach it to the body so what if we just said that the designing had to implementing had to be done by the 29th and then the evaluating had to be done by the 1st and then we just kind of have a buffer of 5 days in there to just kind of iterate if we need to and compile everything together. I mean it kind of crunches the implementation down to a week, but I don't know, I think it could be done.

Third, in addition to careful planning, team Gamma was also observed to pursue time-efficient methods. An exemplary case was shown in Table 4-25. When the team discussed to split PDR presentation task among members (see Appendix Q team Gamma's working document in the selected project planning meeting), GL suggested that for step 1 a (studying handouts), 1 b (identifying general needs), and step 5 (implementing solution – computing potential solutions), the team could assign a specific person to take care of particular presentation slides for PDR. BZ suggested that it was better to separate the team into two sub-teams by teaming students at the same DST together in solution implementation. Based on what BZ suggested, BK proposed that the sub-team should be composed of students from the two different disciplinary tracks but at the same university (see Appendix T for student DST and university distribution). Both BZ and GL agreed on BK's suggestion and they commented that it was the most time-efficient way to complete the steps if the two different-DST students at the same university would work as a sub-team.

Table 4-25

Example of Looking for a Time-efficient Work Strategy _ Gamma Project Planning

Line No.	Participants	Conversation transcripts
1	BZ	So like to go back on what we talked about earlier, do we want to just throw a name on each of these steps that that person can be charged to making the slides maybe just to get some names on here, I think that would be good for when we present the plan to PDR.
2	GL	Yeh I mean I guess that's probably... because I mean really a lot of this stuff is all of us doing our own thing for a while and then coming back and meeting and then for example, 6 evaluating designs it's like all of us are doing that so really the only place that you can specifically break up who does what is in like 5 and like that's like 1 a and b and 5 the only thing you can put a specific person to so it is fine though if you, it would be good if we assign like who is going to do what slides, you know. I suppose the more names we put on there, the better, I don't know.
3	BZ	Okay so let's just go in quick since we have due dates on pretty much everything, let's put in names where we can. So FEM, who is on the FEM team?
4	BK	I am.
5	MW	Yup that's me too.
6	BZ	Alright and that leaves me and Greg for closed. Do we want to say then during the comparison that we will just pair up. I mean this is real rough and this can all change in the future but like 1 FEM and 1 closed form kind of team up and then 1 and the other guys team up and that way we can just be tackling two candidates design at once. I'm looking at the comparing sets of solutions.
7	BK	Yeh I think that's good.
GL and BK bumped into each other so Greg said:		
8	GL	Go ahead Brian.
9	BK	I was just saying it's probably a good idea to have sort of teams of one from FEM and one from closed form doing each candidate's design cause that way they can kind of look to see and make sure the solutions that are coming to are correct.
10	BZ	Yeh, maybe this isn't the spirit of using the distance learning but what do you guys think about having the teams be the two University A and the two University B just because then we can meet in person if we needed to.
11	GL	Yeh that's probably the best idea because it is a little bit cumbersome to have to do this via the internet so uhm, and that way we could just be in person in our design studios and just kind of get it done so yeh that works, that's fine. But I guess it definitely will save us time if we kind of split up looking at the solutions which I think at this stage is probably as you guys said is probably really wise because you know, we are not looking for like the best solution and maybe not the most accurate but it is just kind of getting an idea of what works so I am sure in the later stage of the project we will all kind of collaborate and look at each design but this is definitely the most time efficient way.

As a summary, Gamma students showed several temporal planning behaviors which are promotive to team collaboration. These behaviors include cases such as GA insisted on scheduling sufficient preparation time for PDR presentation; BK and BZ did extra work on thermal analysis to ensure the accuracy of the results; BK finished individual work ahead of schedule so that he could start to work on PDR presentation 11 days before the PDR due date, and the team did not mind working over the weekend. In response to research question 1-2 regarding how individual behaviors may affect team performance, data suggested that students' willingness and efforts on taking extra work were effective at boosting motivation, fostering collaboration, facilitating each other's success, and promoting the team's progress on their design project.

To address research question 1-2 regarding how individual behaviors may affect team performance, Gamma students' promotive efforts shown in their individual temporal planning behaviors contributed to the team's formation of time awareness norm and behaviors. In response to research question 2 regarding team behavior patterns, data suggested that strong time awareness seemed emerging from team Gamma's teamwork process. Such time awareness continued across the three meetings and led to the team's continuation of time awareness behaviors including: (1) the team completed all scheduled tasks within meeting periods, (2) the team made a solid project plan and scheduled a reasonable number of meetings to work on their preliminary design and presentation, (3) the team had meeting agendas posted and the team followed the meeting agenda to guide their discussion and monitor time use, and (4) the team emphasized early preparation and used time-efficient methods to ensure good quality work within the limited task period.

Technology use.

Students' use of technology showed interesting behaviors therefore these data were reported in this section. In response to research question 1 regarding individual behaviors in technology use, Gamma students regularly used video, audio, and Whiteboard. Students used Whiteboard to display meeting documents (e.g., task description, meeting agenda) and used the pen tool in Whiteboard to jot down discussion notes.

Chat was occasionally used to complement conversations. Students used chat when they did not want to interrupt the team conversation. The team spent about 0.7%[5] of their time on using chat in Lab 1 meeting and 0.03%[6] of the meeting time in the selected project planning meeting. No chat was used in the team's selected project working meeting. Several tutoring behaviors were observed when students helped each other with the technology questions.

In response to research question 2 regarding team behaviors in technology use, team Gamma experienced few technical issues or audio/video cut-outs during the selected meetings. The quality of team Gamma's meeting video and audio stayed stable in the three selected meetings. Emails and team's dropbox were used to exchange documents, report each person's work, and address issues out of the SameTime meetings. Team Gamma was never observed to use shared application in the selected meetings, which may be because the instructor warned students that using shared application would slow down the web speed and reduce audio and visual quality. Regular technology normalization and use of basic communication tools may be reasons that team Gamma experienced few technology issues and had stable video and audio transitions. Team Gamma may view completion of the tasks as the team's first priority or they were task-focused and barely have time to experiment with new technology. Therefore, they chose simple tools that could satisfy their basic communication and collaboration needs. They were likely to follow the instructors' warning and did not use tools which may serve more functions but can slow down the team's progress in completing the design project.

[5] The rate should be lower because students often typed in chat when they were talking at the same time – part of their chatting time overlapped with their conversation time.

[6] The rate should be lower because students often typed in chat when they were talking at the same time – part of their chatting time overlapped with their conversation time.

In a summary, a high level of interdependence gradually formed and developed in team Gamma students' promotive behaviors and interactions in task management, temporal planning, and technology use. In response to research question 1 regarding individual behaviors in an interdependently-structured task setting, interdependence seemed gradually forming in student behaviors in: forming an organized discussion and problem-solving sequence, planning project steps and being cautious of time use, using effective problem-solving and working strategies (e.g., recapping) and tools (e.g., meeting agenda) to organize team discussions and within-meeting task completion, conducting regular technology normalization and using simple communication tools to maintain their meeting quality, and communicating technology issues and looking for timely solution. Such behaviors and actions continued across the three meetings. In response to research question 1-2 regarding how individual behaviors may affect team performance, students' promotive behaviors increase their opportunities to do well in collaboration. Such promotive behaviors contributed to individual learning and the team's success in completing high quality work in a timely manner.

Decision-making.

Team Gamma's decision-making behaviors and strategies were reported in two areas: information communication and reaching decisions. The information communication was discussed in three aspects: (1) what information was being shared and communicated, (2) how information was communicated (e.g., strategies to ensure effective communication and mutual understanding), and (3) how Gamma students' information communication behaviors may influence member interaction, team collaboration, and team performance (outcomes of the team's information communication).

Information communication.

Information being communicated.

In team Gamma's Lab 1 and selected project planning meetings, majority of the informative conversations were to inform actions, deliver individual work, offer technology knowledge, share personal findings, and report issues encountered in the problem-solving process (see Table 4-26 for examples).

Table 4-26

Examples of Informative Conversations _ Gamma Lab 1 & Planning Meetings

No.	**Participants**	**Conversation**	**Informative Comm. Functions**
Example 1	BZ	Hey guys.	Informing one's presence
	BZ	I'm reading through the document right now to see what's involved. The meeting normalization we pretty much just did.	Informing action and team progress
Example 2	GL	Yeh okay that's fine. I'll take care of the meeting minutes this time, that works for me, I haven't done that yet.	Informing action
Example 3	GL	Yeh Mike, I can't really. You kind of broke up for a bit,	Informing another member's tech issue
Example 4	GL	So the other, speaking of the thing with the matches and the oxygen, that was, I put the signal flares. I have those ranked at 11 and everybody else has those at either 3 or 5	Informing individual item ranking
Example 5	MW	Aw that is the sheet right there.	Informing personal finding
Example 6	BZ	So if you guys click on, go to the main course website on the left hand bar, there's a survey button and then you'll see lab 1 survey. I think that's all we have to do.	Informing personal technology knowledge: tutoring
Example 7	BK	Friday after 4 works for me.	Informing personal schedule
Example 8	GL	Okay, see you Friday.	Informing to leave (action)

Compared with the informative conversations communicated in the previous two meetings, the informative conversations, in team Gamma's selected project working meeting, delivered more design project details than merely informing actions or behaviors. Information being communicated in this meeting included: completed or planned actions, research findings, in-class or out-of-class knowledge sources, analysis results, special design situations, and personal schedules (see examples in Table 4-27 below).

Table 4-27

Examples of Informative Conversations _ Gamma Project Working Meeting

No.	Participants	Conversation transcripts	Informative Comm. Functions
Example 1	MW	Greg was around here somewhere I don't really know what he just… but he ran out and I haven't seen him so I don't know.	Informative: informed the team that GL was not present at the moment
Example 2	BZ	Brian kind of following up on what we were talking about yesterday. I ran some preliminary numbers on kind of a worst case scenarios	Informative: informed BK about the work he had done
Example 3	BK	We could definitely do 30 degrees it just takes like about a centimeter and a half to get about a 15 degree re-entry temperature change.	Informative: informed mechanics
Example 4	BK	Oh okay, let me take a look at that.	Informative: informed the team about the action he was going to make
Example 5	GL	Sorry I'm late guys. I kind of got held over in another meeting with the professor.	Informative: informed the team of his arrival and explained that why he was late
Example 6	GL	Yeh so anyways uhm, I don't know where you guys were as far as today discussing what we were planning on talking about on Tuesday, I just wanted to let you know from my end, I was looking into attachment methods for the, whatever we decide to stick in there between the two plates. Specifically, I looked into like using adhesives, some sort of like adhesive pads or, I don't know, whatever blue or something like that, and I found actually quite an amazing engineering firm who specializes in this kind of stuff and it turns out that they actually adhesives are used for reusable launch vehicles and a lot of different aerospace structures and this company actually deals with manufacturing these adhesives so it is actually a real thing that takes place for aluminum lithium and for sandwich structures we are looking at,	Informative: shared with the team of his adhesive research findings
Example 7	GL	So I had, I'm not sure what I missed due to my lateness of this meeting. But I just had some general, I talked with Professor Davidson, actually that is why I was late, I didn't realize I was in his office past 12:30. Uhm, but I've got some kind of good information about where we probably need to go for this PDR and so if you think back in the brainstorming section we had said, "Ok we are going to break the University B guys, you guys are going to look at either the simple blade stiffened panel and you know, here at University A we are	Informative: informed the team about the content of his meeting with the professor

No.	Participants	Conversation transcripts	Informative Comm. Functions
		going to look at the hat panel, it had the little hats in the middle for the stiffeners." So first off, looking at those two designs I went down and I talked to Davidson and I asked just to see if we were kind of thinking along the right lines and he said you know that that sounds great, the blade stiffened panels is definitely a good conservative approach. You know, as far as getting something done for the PDR, that's a good thing to have done. With respect to the sections with that hat however, he said the chances of us being able to get that done by PDR are absolutely zero. The funny thing is though, is that when I told him about the hats section, he had asked if I had talked to Zendor and he kind of laughed, so I have no idea, you know, he basically said like it seems like a viable option, but if we decide to analyze that hat structure, or the hat stiffeners, that is going to be a really big investment in our team's time and so we have to think about, for some reason though I feel like it actually is a really good design.	
Example 8	BK	Okay on the file I put on the website, it has the maximum temperatures during re-entry and it is there, I put a few different cases for different insulator thicknesses so if we just want to pick one of those, I guess we can just say for the time being, that's our max temp.	Informative: shared with team about the detailed content in his work
Example 9	GL	So does that mean like I said, it is hard for us at University A to kind of perfectly visualize what exactly you guys had done.	Informative: informed the University B students about the difficulties to visualize their work
Example 10	BZ	Real fast, Brian K can get to basically all of these workbooks are under, if you go into the AIDE, you go to course content full class, go up to assignments and go to the very first assignment which is design project information and in there, the SSE material properties, that lists the material properties with the knockdown factor. Knockdown factor just means you multiply whatever property you are looking at by that factor and that's what the value is at that temperature, so.	Informative: informed BK the location of the workbooks and tutored BK about the definition of the knockdown factor
Example 11	BZ	I am free all day Sunday.	Informative: informed the team of his schedule
Example 12	BZ	Ok, well uhm I personally I know it is a lot more work, maybe you can agree or disagree Greg, to do a sandwich with two stiffeners. My code is all set up for just the milled out biaxial stiffeners with only one face sheet, so I mean we can do it, it is just going to make me shift gears, but if that's, I know it is a better design,	Informative: informed the team about the outcome of changing the design at the moment

In response to research question 1 regarding individual behaviors in information sharing, data suggested that Gamma students usually provided detailed description when sharing information or ideas, including related information and data. The purpose of such behaviors is to offer team members sufficient knowledge about the shared information or ideas. Such related information included knowledge sources (e.g., research paper, authorized database, the course instructor), rationale behind an idea, and calculation or analysis processes. As shown in the sixth example in Table 4-27, GL informed the team about the adhesive he found for the team's preliminary design solution in the project working meeting. He also introduced relevant information including the company where the adhesive was produced and areas where the adhesive had been applied to. With the information provided by GL, the team then may form a better judgment to evaluate whether the product was suitable for their design.

How students communicated information.

In response to research question 1 regarding individual behaviors in information sharing, Gamma students were observed to use several strategies to ensure accurate and mutual understanding was shared among them. When a student (the speaker) shared information or ideas, he was often observed to check listeners' understanding by summarizing information and asking for confirmation (see examples in Table 4-28).

Table 4-28

Speakers' Actions to Ensure Information Communication _ Gamma Project Planning

Line No.	Participants	Conversation transcripts
		Example 1
1	GL	So I guess the deal is you guys all got my email with the kind of level 1.5 plan we came up with the last time?
2	BZ	Yeh I got it.
		Example 2
3	GL	So I guess the only thing we kind of need to do I think, we were in discussion last time is like the level 2 plan we just have to put dates in there, like when things need to be completed by and where I guess each of those specific tasks, you know, who that falls to…
4	BZ	Yeh I think that's all we need to cover today is just get more specifics and some dates on there and maybe who is going to do what.

The listeners were observed to frequently provide *verbal acknowledgement* or *summarize* the speaker's shared information or ideas to confirm their understanding (see the first and second examples in Table 4-29). In the first example, BK suggested that the team could start from the room temperature for testing the Delta T in the design. If the Delta T was negative, it meant the temperature should be lower. BZ acknowledged BK's idea by commenting: "that's really a good idea actually. I like it a lot". In the second example, GL suggested that all students should work on different components of the design. BZ then tended to confirm his understanding by summarizing GL's suggestion "…so we are all going to hit the same design just from two different angles I guess, one at the University A team and one at the University B team, just to check our answers I guess, is that basically what you are suggesting?" Students also liked to use languages such as "*Just to confirm*…" or "*does that mean*…" to check whether their understanding and interpretation of the speaker's shared information was correct (see the 3rd and 4th examples in Table 4-29).

Table 4-29

Listeners' Actions to Ensure Information Communication _ Gamma Project Working

Line No.	Participants	Conversation transcripts
		Example 1*: verbal acknowledgement*
1	BK	…what we could also do is uhm, we could change around we're kind of assuming that our room temperature is where we want to have it at its equilibrium value, I guess we could say during manufacturing maybe start it off at a lower temperature or something like that if we are seeing the most delta T in the negative direction or something, I don't know.
2	BZ	That's a really good idea actually. I like that a lot,
		Example 2*: confirm the understanding by summarizing the speaker's ideas*
3	GL	…what I was thinking was, why don't we just choose a design we want to pursue and not make it something very, not make it like the most difficult thing and rather let's just do a better job of that and make sure in the PDR because so much of what we are being evaluated on in the PDR is how well do we know this information, how well can we carry out this design on a basic panel. So I feel like if we, given the time we have, it might just be better if we all just push towards a simpler design and just say, "Hey look we are able to do this successfully, so now in the CDR, now we will start looking at all optimizing it." So certainly, let me know what you think about that but that's where I am kind of standing at this point just because I am worried about time and having to make that presentation.
4	BZ	Yeh that sounds like a perfectly reasonable plan to me. It kind of sucks that we aren't going to be able to get that done, but I think we all kind of knew that was going to be hard anyways going into it so, yeh I agree with you, let's try and decide, so we are all going to hit the same design just from two different angles I guess, one at the University A team and one at the University B team, just to check our answers I guess, is that basically what you are suggesting?
5	GL	Yeh I would say, uhm, I know definitely from, well FEA is going to be the same too, but Brian Z, I know that you and I have been developing these massive spread sheets and stuff and we're crunching the numbers and going through that so uhm, that's what I was saying like, if it, you know, I think it is much more important that we get a good panel design so I think that we can you know, use working on one design as kind of a springboard for us kind of getting more of a correct answer so that is exactly what I am saying is I can, Brian Z and you and I will communicate and kind of compare our numbers and then Brian K and Mike, you can look at the FEA and in that sense, just ensure that, because really the PDR is our first step in trying to design a panel so it is more important to get down the fundamentals because Davidson said, he is like, you know, if you take a riskier approach and you end up getting the PDR and not having that design actually work, that means after your PDR you have to then spend time figuring out how you went wrong in the PDR. So what we are going to try to avoid having to do is going back and trying to fix our problem so I think rather than, I think our real goal should be have a successful correct design for PDR and that's why I am saying I think the best approach right now given the time we have is really just look at one design and you know, balance our answers off of each other and in that sense, allow us to have a much higher probability of a correct answer.
		Example 3*: use "just to confirm" to confirm understanding*
6	BK	Well I was just telling you numbers for just the insulating tile thickness. We also have to consider there is going to be a nomex in between there plus a little strip of RTV underneath that. So I think if you give us like one and a half centimeters for all that stuff together for all the TPS components, that should be fine cause with the centimeter, I forget the exact number, it was 45 degrees so if we do a centimeter of tile, that gives us a little under a delta T of 100 degrees cal vent from the lowest

Line No.	Participants	Conversation transcripts
		temperature we will see up to the maximum temperature we are going to see. So if we do somewhere in that area, that is kind of the ballpark.
…		
7	BZ	…*just to confirm* it one more time because I don't have this number right, then basically everything I do for the next week is going to be ruined, but we are going to assume we have used up a centimeter and half of our total available height in insulation so the rest of that room we can use for structure and we are going to assume that a maximum delta T that the stiffened sheet is going to see if 15 degrees C? Is that right?
		Example 4*: use "does that mean" to confirm understanding*
8	BK	The thermal stuff is already done. Greg I did the thermal stuff over the week. I just need to run the ascent case, but that stuff is already done.
9	GL	OK. Wow that's pretty awesome! So when you say you've done the thermal stuff, does that mean that you are able to give us a temperature that is directly outside of the plate basically to those load cases?
10	BK	I got you the surface temperature for the structural components. I just put it up all on the TM website thing, so you can go check that out.
11	GL	Alright awesome, okay that makes me really happy cause I had no idea that was …

When listeners did not understand the shared information, they were observed to ask for clarification or elaboration. As the example shown in Table 4-30, BK asked the team whether he should find more information about the insulator and the temperature variation. BZ was not quite sure what BK referred to; therefore, he asked BK to clarify the question.

Table 4-30

An Example of Information Elaboration _ Gamma Project Working

Line No.	Participants	Conversation transcripts
1	BK	Also I did make some approximations when I did this simulation. I didn't have any of the material properties vary with temperature, I just kind of used the room temperature ones, do you guys think I should try and find more information about the insulator and see if I can find the temperature variation?
2	BZ	You are saying you didn't change the properties of the insulation, not the, you didn't look at the properties of the titanium lithium? Which material are you talking about?
3	BK	Uhm, I am talking about the insulating material of, I didn't change any material properties for either case though. I don't really, I kind of just used a base line number for the metal portion. I forget where I found it from, so I probably want to, someone else may have looked into it more, I should probably use their values for it too.

Explanation was usually given in a timely manner and at an appropriate level of elaboration so that the members were able to understand the shared information well. As shown in the exemplary conversations in Table 4-31, BZ suggested some specific activities and work that each member should be doing on the following Friday. GL agreed with BZ's suggestion and explained the importance of being specific on the team's project needs at the beginning of the project. Part of GL's explanation sounded repetitive of BZ's words; however, his elaborative explanation implied he paid attention to the quality of the team's project work. BZ continued to confirm the importance of identifying the project needs and encouraged all members to develop an individual list of the project needs, upon which the team could decide the team's final list.

Table 4-31

Example of Information Communication _ Gamma Project Planning

Line No.	Participants	Conversation transcripts
1	BZ	…on Friday, let's just quickly flesh out a rough idea of an agenda or what we want to accomplish. Let's see, we are going to be identifying the problem and defining the problem so we should definitely study the handout, all of us, read that over a couple of times and really get a good feel for the problem and the factors of merit and stuff like that and be ready to come in with some needs and specifications.
2	GL	Yup, I would agree that is probably the main thing that needs to get done, yeh because to be honest the more time we spend looking at these things in the beginning, the better off we are going to be because if we do a real bad job, you know, identifying what the needs are, it is going to come up and catch us when we are trying to implement the solution, so we should all take a real good look at that and just think about what the different components of the plates are so we can start thinking about who can research what or what needs to be researched. The other thing too is that we can probably along with kind of thinking about what the needs of the project are, is think about the factors of merit cause we will be coming up with those as well.
3	BZ	Yeh, they are kind of listed, but I think we should definitely all come in with if not a formal list, a really good idea in your mind of what you see the most important needs being so that we can then kind of through a process of that one of the first group building exercises we did where we could all start to rank the most important needs that we think the design needs to meet so we can all be on the same page as to what we should really be shooting for during the design.

Data suggested that students carefully evaluated the given information by asking questions from different perspectives. Taking the example presented in Table 4-32 for instance, GL shared the information of the adhesives, which the team could use as the attachment method for the reusable launch vehicles in their design. After listening to GL's shared information, BZ asked about the strength of the adhesive and GL responded that it depended on the materials being used and provided more detailed description. Later, MW asked about the maintenance and inspection abilities of the adhesives. GL responded that he did not research much into it and elaborated that at least the team could continue to research about the adhesive and find out specifics that could be used for attachment. Different opinions and questions suggested by team members to evaluate the adhesive could encourage GL to do more investigation of the material in order to better judge its feasibility and accountability for the team's design work.

Table 4-32

Example of Critical Evaluation of Given Information _ Gamma

Line No.	Participants	Conversation transcripts
1	GL	Yeh so anyways uhm, I don’t know where you guys were as far as today discussing what we were planning on talking about on Tuesday, I just wanted to let you know from my end, I was looking into attachment methods for the, whatever we decide to stick in there between the two plates. Specifically, I looked into like using adhesives, some sort of like adhesive pads or, I don’t know, whatever blue or something like that, and I found actually quite an amazing engineering firm who specializes in this kind of stuff and it turns out that they actually adhesives are used for reusable launch vehicles and a lot of different aerospace structures and this company actually deals with manufacturing these adhesives so it is actually a real thing that takes place for aluminum lithium and for sandwich structures we are looking at, we will definitely be able to use adhesives to bond the plates to the stiffeners.
2	BZ	Were you able to find out anything about the strength of the adhesive, is it just as strong as the materials it is bonding or is it weaker?
3	GL	It, like I said, it depends on the material you are using, but the, I didn’t research into too much into the actual strength of the adhesive itself, although given the temperature ranges that we’re looking at operating in, as well as the loads that we have exerted on the panel, the stiffener should hold as in like the strength of the uhm, because they gave when for the couple of different adhesives, they gave kind of a preliminary I guess you call it strength analysis of the adhesive and those all seem to be sufficient for what we were looking at. Uhm, I would look into that you know, where I got was, there is a whole bunch of candidates for the adhesives that we could end up using if we decide to attach it using adhesives. There is probably somewhere in the neighborhood of like 12 different options and each one of those has a different temperature range it can operate in as well as a different strength, but in those 12 different adhesives, they kind of had a preliminary, like I said a strength analysis saying it would withstand like a certain load and this kind of stuff and just reading that without diving into it too much further, I would say there is about a 90% chance that most of those adhesives are going to be fine for what we are looking at.
4	MW	Quick question Greg about the maintenance and inspection abilities, are they able to come off easy, I mean we talked about the solvent kind of thing, how does that fit in?
5	GL	Just as we were talking about, you know, as far as if you had to repair this, you are going to have to basically scrap the whole panel cause you can’t break the adhesive bonds. Uhm, some of these are able to, I didn’t note exactly which one of these can, but some of these do have the capability for solvents, some of them don’t, it kind of depends. So that is certainly something to be looked into further which I can very easily do,

Outcomes of Team Gamma’s (effective) information communication.

In response to research question 1-2 regarding how individual behaviors may affect team performance, data suggested that team Gamma students’ effective information communication can help reduce confusions and conflicts in people’s understanding. Data suggested that team Gamma students had strong awareness of confusions and misunderstanding which were frequently observed during the meeting discussion. Students paid attention to different opinions, viewed confusions and misunderstanding as team problems, and solved them through open communication. As shown in the two examples in Table 4-33, students were detailed in explaining ideas and shared information so that they were able to obtain a thorough understanding of discussed issues.

The first example is about how the team clarified the confusion in their understanding of the due dates for each problem-solving step. GL was initially confused whether the team had decided the due date for the evaluation of potential solutions. BZ thought GL did not understand the meaning of due dates so he explained his thoughts to GL. BZ also clarified that the team would do brainstorming and evaluation of potential solutions at a same meeting on the 22^{nd} so that the team could start implementation right afterward. GL then confirmed his understanding. GL also realized that the team would do one big meeting by combining brainstorming and evaluation together rather than do two separate small meetings. BZ confirmed with GL's thoughts and continued emphasizing that the meaning of due date was to accomplish both brainstorming and evaluation by the 22^{nd}. Through this discussion, the misunderstanding between GL and BZ was clarified and two issues were clear to the team: (1) the due date meant the team needed to finish the step by the due date and (2) the team would do brainstorming and evaluation in one meeting.

In the second example, BZ gave a detailed explanation of the work he and BK had done. However, GL did not understand well because it was difficult for him to visualize BZ and BK's work without seeing it on paper. So GL summarized his understanding of University B students' work and asked for confirmation. BZ confirmed that GL's understanding was correct. Compared with face-to-face conversation, the video-conference had limitations in delivering communication when complicated drawing of design graphics was required. For instance, students could not get immediate visualization of the data because sharing a large amount of data or visual data can decrease the bandwidth speed and significantly slow down the meeting progress. Under such circumstances, detailed and accurate explanations were critically important to help reduce confusions and keep communication going. Data also confirmed that explanations must be reciprocal because confusion can come from both speakers and listeners. Therefore, for effective communication, not only speakers need to ensure that a good explanation was provided to the audience, the listeners are also responsible to express his confusion to the speakers.

Table 4-33

Examples of Effective Communication to Avoid Conflicts_ Gamma Project Planning

Line No.	Participants	Conversation transcripts
		Example 1
1	GL	Wait so what is the uhm, the due date for the evaluation of potential solutions? What did we decide on that? Is that going to fall like two or three days later than the 22nd or what is happening with that?
2	BZ	See I was thinking of the due date. When I say due date I kind of like assuming that basically accomplish everything on the day of the meeting. I mean maybe I am wrong, but it seems like up until this point, like we are going to be doing the brainstorming and doing the evaluating during the meeting so it's kind of like the day, like the 22nd would be the day if we met on the 22nd we would pretty much be done with the brainstorming and evaluating. So then we could launch right into implementing right after that.
3	GL	Ok, yeh I understand that. For some reason I was just thinking that we were trying to set up another meeting to evaluate potential solutions, so right now we are looking at, which is fine, we are just looking at one big meeting before the 22nd to do the brainstorming and evaluating the potential solutions. That's, we're not going to do two little ones.
4	BZ	I think that is what we are saying. And if we meet on Saturday and maybe have that meeting and then decide later that we need another one on Sunday, we can do that. We are just saying we need to be done with it all by the 22nd, however, we get there, we are just saying we need to be done with that for the 22nd.
		Example 2
5	BZ	…what I did was took the minimum material properties that we will see over the operating range because I didn't know what temperature range we were looking at so for this first cut I just want to be as conservative as possible so I can post this but like I said, we're not going to see material properties this low, but I think it is a good conservative thing to start with unless our design ends up being impossible, then I think it is good to go with worse case scenario just because it is too hard to deal with all of the possibilities right off the bat.
6	GL	So does that mean like I said, it is hard for us at University A to kind of perfectly visualize what exactly you guys had done. Are we at a point right now that if we go ahead and let's say we analyze a sandwich structure with biaxial blade stiffeners so from what I gather, we are at a point where we are saying let's assume we've got 1.5 centimeters for the whole TPS, the tile pad and everything so given that we then at this point we have delta T or the surface temperature of that top plate, is that what we have at this point?
7	BZ	Yeh exactly.

Reaching decisions.

Effective information communication can facilitate the establishment of mutual understanding and further result in good decision-making. Further, good decision-making does not only rely on effective information sharing. In response to research question 1 regarding individual behaviors in decision-making, data suggested that Gamma students used strategies such as critical reviewing of shared information, challenging assumptions, reasoning, argumentation, suggestions, explanation, and summarization. New ideas were generated through discussion of multiple perspectives. Decisions were made based on mutual understanding and sound reasoning.

The first example in Table 4-34 is about how the team reached a decision on the ranking of the portable heating unit by *challenging* each other's assumptions in Lab 1 meeting. In this example, BZ proposed to rank the heating unit low because he did not see it having much effect. BZ also assumed that the heater would not give sufficient heat when the team landed on the cold side of the moon. BK *challenged* BZ's assumption and provided his assumption that the space suits should be well insulated and continued to give reasons for his assumption. The team agreed with BK's assumption. The team reached an agreement on ranking the heating unit as number 12 and this decision is based on team's open discussion of assumptions and reasons shared by BZ and BK.

Table 4-34

Example 1: Reaching Decisions / Agreement by Challenging Assumptions _ Gamma Lab 1

Line No.	Participants	Conversation transcripts	Comm. Functions	Decisions / Agreements
1	BZ	I'd say the portable heating unit cause for the next lowest,	Responsive to Q	
2	BZ	I don't really see how that's going to have that much effect if you go to the cold side of the moon, I'd forget the number, but you know it's some ridiculously low temperature, a plug in heater isn't going to do anything.	Reasoning	
3	BK	Well how long does the night last for? Like if we're going 250 miles or kilometers or whatever, that's going to take a long time, what do we have to be on the dark face of the moon during that do you think?	Interrogative	
4	BZ	That's a really good point and I have no idea.	Responsive to Q	
5	BZ	I mean I'd assume that our space suits are fairly well insulated because whether the dark side or the white side, it's either super hot or super cold. I mean even just in between the sun and the shadow, if you get into a shadow it's super cold so maybe I'm giving too much to our space suits but I feel like their insulation is going to be all the protection that we need otherwise we wouldn't even survive five minutes.	Reasoning	
6	BK	I'll buy that.	Agrees	
7	GL	Yeh it is a good point cause you don't ever see like pictures of astronauts like on the moon with like a tote behind heating unit so that' a really valid point, I assume that the space suits are I guess can encompass those temperature variations so in that case that would be pretty useless so we put that at 12,	Reasoning	
8	GL	is everybody okay with that?	Interrogative	
9	MW	Yup that works for me.	Responsive to Q	
10	BK	Sounds good.	Responsive to Q	Agreement on heating unit ranking

The second example in Table 4-35 and example 3 in 4-36 showed that Team Gamma also used *reasoning* and *argumentation* strategies to reach an agreement in Lab 1 meeting. In the second example, students were working on individual ranking and BZ reasoned that the team should assume there was some way to get the food or water into the space suites. GL agreed with BZ's reasoning and also offered his reasons. After hearing GL's reasoning, BZ added that if the team did not make the assumption then four out of fifteen items would be knocked off. This aligned with BZ's survivability strategy for ranking the items. So GL asked for confirmation and BZ agreed that the team should assume there was somehow some way to get the food into the suit. The team reached the agreement on the assumption (i.e. that there was some way to get the food or water into the space suites) and this agreement was built upon the reasoning contributed by two members in the team.

Table 4-35

Example 2: Reaching Decisions / Agreement through Reasoning _ Gamma Lab 1

Line No.	**Participants**	**Conversation transcripts**	**Comm. Functions**	**Decisions / Agreement**
1	BZ	I wonder if we are to assume that there is a way to get the food or water into the spaces suites because you can't really see popping your helmet off to take a drink	Reasoning	
2	GL	When I was reading that, that was kind of the first thing that came to my mind because it's like how do you get those fluids and foods in body.	Agrees	
3	GL	I'm kind of on the, I'm thinking that you really can't get the food or water into your body unless it's like internal to the space suit but it doesn't specify that so I'm not too sure cause I would say don't take the food or water if it's external.	Reasoning	
4	BZ	Right I agree.	Agrees	
5	BZ	But we have to assume that there is some way of consuming it otherwise that knocks off like four things from the list, completely useless.	Reasoning	
6	GL	Alright so uh so then we are going to assume that we can continue…water. Is that the plan?	Interrogative	
7	BZ	Yeh I think we are going to assume that there is somehow some way that you can get it into your suit.	Responsive to Q	Agreement on making the assumption

The third example showed that team Gamma members reaching an agreement by using the strategies of *challenging* partner's ideas, providing *argumentation* to justify their points of view, and offering further *explanation*. When the team discussed the rankings for compass, signal flares, and the FM receiver, GL asked whether these three items should be ranked low at 11, 10, and 9 at the bottom of the list. BK *challenged* GL's suggestion by *arguing* that the team could use the signal flares to signal whoever may come to rescue the team. BZ agreed with BK's argumentation and explained that he thought the team needed something to communicate with the rescue people other than FM receiver. BZ's suggestion was confirmed by other team members. BK then reminded the team by *explaining* that if the team kept the FM receiver then they need to assume the receiver works on the moon. The team's discussion was interrupted when BZ asked whether GL could upload the team's individual rankings and team rankings to the Whiteboard. After individual rankings and the team ranking were uploaded into the ranking table on the Whiteboard, GL continued his question regarding the rankings of compass, signal flares, and FM receiver. BZ responded that he thought the signal flare should be ranked at six instead of lower ranking because it was important based on the team's discussion. BZ also suggested the team should focus on items which were most important to them when discussing about the ranking for the rest items. GL then agreed that the signal flares should be ranked at six.

Table 4-36

Example 3: Reaching Decisions / Agreement through Argumentation _ Gamma Lab 1

Line No.	Participants	Conversation transcripts	Comm. Functions	Decisions / Agreement
1	GL	…what do you think is the out of the magnetic compass signal flares and the receiver, what do you think is the least useful of those, cause we'll put those at 11, 10 and 9 positions but it's more just the order I guess.	Interrogative	
2	BK	Don't we need the signal the ship somehow though?	Interrogative	
3	BK	Like I know if you are getting rid of all those they kind of, the people that are coming to rescue us have no idea what we're doing should we keep like one thing so we can try to signal them?	Argumentativ e	
4	BZ	Yeh I see what you are saying, other than the FM transmitter what other signal can we give them to communicate other than words, "here we are", cause the signal flares kind of show where we are. I don't think we have any other way of communicating with them unless we keep the transmitter which I think we all kind of agree is speculative.	Responsive to Q	
5	BK	Well if we assume it works I think it's a good idea to keep it but if we are going to take the assumption that it doesn't work, then yeh I guess we can dump it.	Explanative	
6	BZ	Yeh, if we assume that it works I think it's a really important thing to have. But like I say, if we decide what we want to assume.	Repetitive	
The conversation was interrupted by BZ's request of GL to upload individual and team rankings onto the Whiteboard so that all members can see them at the same time. For the next few minutes, the team was working on using Whiteboard pen tools to fill in individual rankings and the team ranking into the ranking table the instructor provided to them.				
7	GL	…basically we can put the magnetic compass, signal flares and the receiver at eleven, ten and nine I guess. I guess it matters what the order is, do we have a vote for which one of those is going to be the least useful?	Interrogative	
8	BZ	Well uhm, now that I think about it, we all kind of thought that those, like at least the signal flares were kind of important but they just didn't fit on our top list, so maybe that should go as six since we can't bring anything else with us.	Responsive to Q	
9	BZ	Now it's just kind of ranking what we think of the stuff we can't bring, what's the most important.	Suggestive	
10	GL	Yeah now that's a good point. We can put the, since we were kind of on the fence about the flares, we can we'll stick those at six.	Responsive to S	Decision reached on signal flares ranking

When it came to project planning and working meetings, strategies like *explanation, elaboration, suggestion*s were more frequently observed than they were used in Lab 1 meeting.

In response to research question 2 regarding team behaviors in decision-making, data suggested that Gamma students, when working as a team, had maintained accurate, mutual understanding through communicating information, asking questions, clarifying confusions, providing timely, explicit explanation and responses, and adding complementary notes. Students' explanative, elaborative, and suggestive conversations were observed to increase. Based on mutual understanding of information, the team was observed to produce new knowing as well as make vigilant decisions through challenging assumptions, complementing each other's ideas, and critically evaluating given information and perspectives. As a result, a high level of interdependence was gradually formed and maintained from team Gamma students' behaviors as listed above.

Section 1 reported individual and team behaviors of team Gamma, documented behavior changes across the three selected meetings, and described how individual and team behaviors may be associated with team performance. Table 4-37 summarized team Gamma's individual and team behavior information in response to the two research questions.

Table 4-37

Team Gamma Behavior Summary in Response to Research Questions

Evaluation Aspects	**RQ1-1 What individual behaviors are observed and how do these behaviors change over time?** **RQ1-2 How may individual behaviors affect team performance?**	**RQ2-1 What team behavior patterns are observed?** **RQ2-2 How do team behavior patterns and students' interactions change over time?**	**RQ2-3 How may student interactions and team behaviors affect team performance?**
Communication	Individual Gamma students consistently showed behaviors: 1.When entering a meeting, students greeted each other, ensured members' presence, and did quick technology normalization to check the stability of Sametime video and audio 2.Students handed over turns by asking specific questions or naming a student 3.Few disruptive behaviors or conversations were observed 4.Responded questions and suggestions in a timely manner a. Questions were responded with direct, explicit answers; for indirectly-responded questions, clarification was asked for or complementary comments were provided 5.Affective conversations were task-related to show peer respect and foster positive working morale 6.GL, BK, and BZ had increased participation	Team Gamma were consistently observed: 1. Formed a habitual entering-meeting behavior pattern / norm as a team 2. Built tightly-connected conversations through smooth turn-taking and timely responses 3. Stayed focused on task-related activities 4. Maintained high response rates (100% response rate to questions and 97% response rate to suggestions) with timely responses and explicit explanation a. Provided explicit explanation in responses foster new knowing and ensure mutual understanding 5. Carried on positive interpersonal relationship and maintained strong, positive working momentum 6. Participation grew evenly among GL, BK, and BZ	Data suggested that individual Gamma students showed promotive communication behaviors, which may contribute to enhanced team collaboration, continuation of team-like behaviors, increased participation and working motivation.

Evaluation Aspects	RQ1-1 What individual behaviors are observed and how do these behaviors change over time? RQ1-2 How may individual behaviors affect team performance?	RQ2-1 What team behavior patterns are observed? RQ2-2 How do team behavior patterns and students' interactions change over time?	RQ2-3 How may student interactions and team behaviors affect team performance?
	Inconsistence in student behaviors: MW's participation continuously decreased across three meetings		
Planning	Individual Gamma students consistently showed behaviors:	Team Gamma were consistently observed: 1. Formed an organized discussion and problem-solving sequence by using effective problem-solving strategies (e.g., ranking strategy in Lab 1), organizational strategies, (e.g., recapping) and tools (e.g., meeting agenda) 2. Planned project steps and was cautious with time use; completed scheduled tasks within meeting periods 3. Regularly conducted technology normalization and used simple communication tools to maintain meeting/communication quality 4. Communicated technology issues and looked for timely solutions	Data suggested that the team's organized meeting sequence, strong time awareness, and technology use behaviors may contribute to team productivity and increase the team's opportunity to succeed in completing tasks with high quality and in a timely manner.

Evaluation Aspects	RQ1-1 What individual behaviors are observed and how do these behaviors change over time? RQ1-2 How may individual behaviors affect team performance?	RQ2-1 What team behavior patterns are observed? RQ2-2 How do team behavior patterns and students' interactions change over time?	RQ2-3 How may student interactions and team behaviors affect team performance?
	Task management: 1.Individual organizational conversations helped them stay focused on completing scheduled tasks: to guide members' behaviors, to summarize completed actions, and to suggest future actions 2.Developed the team's seven design steps to guide its design process 3.Used strategies such as recapping and summarization to manage task-related discussion: recapping helped remind individual responsibilities and ensure no task was missed; summarization helped sum up completed actions and evaluate project progress and teamwork status. 4.Routine tasks were regularly scheduled, delegated, and completed. Students carefully learned about task requirements and usually rotated on or volunteer for routine tasks 5.Ensured the task completion status by regularly checking whether all necessary content were included and correct formatting was used 6.Either followed task description or meeting agenda to plan or work on tasks; used effective working strategies to guide problem-solving discussions; usually completed one task then started a new task	*Task management*: 1. Used organizational languages to guide behaviors and suggest future actions; used strategies such as recapping and summarization to organize task-related discussions; used the team's design steps to guide its design work 2. Meeting conversations followed an organized sequence: beginning with technology normalization, continued with lab or design task discussion, and ended with team's routine task discussion and delegation; Discussion of a new item would not usually start until the team finished the previous item 3. Followed either task requirements or meeting agenda to schedule tasks and evaluate task completion status	

Evaluation Aspects	RQ1-1 What individual behaviors are observed and how do these behaviors change over time? RQ1-2 How may individual behaviors affect team performance?	RQ2-1 What team behavior patterns are observed? RQ2-2 How do team behavior patterns and students' interactions change over time?	RQ2-3 How may student interactions and team behaviors affect team performance?
	Temporal planning: 1.Developed clearly-written task goals and outcome description in meeting agendas. Used meeting agenda to organize students' design activities and manage within-meeting work time 2.Regularly updated and shared individual working progress with peers, which helped the students to gauge the team's progress and plan for timely adjustment 3.Carefully planned work time including (1) worked backward to schedule working time for each problem-solving step, (2) was willing to work over weekend, (3) pursued time-efficient method, and (4) individual promotive efforts such as GL's insistence on scheduling sufficient time for work and emphasis on early preparation, BK and BZ completed their portion of work ahead of the team's scheduled deadline *Technology use*: 1. Individual students completed technology normalization when entering the meetings 2. Chose simple tools to satisfy basic communication needs; few technology issues were observed	*Temporal planning*: 1. Scheduled tasks were consistently completed within meeting periods 2. Constantly updated individual work progresses; made timely adjustment to the design project work when needed 3. The team regularly posted its meeting agenda and the team used the meeting agenda to guide their discussion and control working time for each scheduled task 4. The team emphasized early preparation and used time-efficient methods to ensure high quality work within the limited time period *Technology use*: 1. Regularly conducted technology normalization 2. Use basic communication tools	

Evaluation Aspects	RQ1-1 What individual behaviors are observed and how do these behaviors change over time? RQ1-2 How may individual behaviors affect team performance?	RQ2-1 What team behavior patterns are observed? RQ2-2 How do team behavior patterns and students' interactions change over time?	RQ2-3 How may student interactions and team behaviors affect team performance?
Decision-making	Gamma students consistently showed behaviors: 1. Information was shared with great details and explicit explanation 2. Used strategies such as asking, explaining, summarizing, acknowledging, and confirming to ensure members' mutual understanding of shared information 3. Stayed awareness to confusions and misunderstanding. Confusion and misunderstanding are addressed with timely explanation and clarification 4. Carefully evaluated given information (by asking questions) from different perspectives 5. Shared ideas and perspectives were thoroughly reviewed, discussed, and evaluated. Students used strategies such as challenging assumptions, providing arguments to justify views, and offering reasoning and explanation. Decisions were made based on students' mutual understanding of the problem and shared information and sound reasoning of alternatives 6. Use of explanation, elaboration, suggestions was observed to consistently increase from	Team Gamma was consistently observed: 1. Maintained accurate, mutual understanding through communicating information, asking questions, clarifying confusions, providing timely, explicit explanation and responses, and adding complementary notes 2. Use of explanation, elaboration, and suggestions were observed to consistently increase 3. Generated new knowing and made careful decisions through challenging assumptions, complementing ideas, and critically evaluating given information and perspectives	Data suggested that: 1. Team Gamma's continuous, effective information communication may contribute to the team's establishment of mutual understanding and further result in good decision-making 2. Data suggested that new ideas were generated through members' open discussion of multiple perspectives.

Evaluation Aspects	**RQ1-1 What individual behaviors are observed and how do these behaviors change over time?** **RQ1-2 How may individual behaviors affect team performance?**	**RQ2-1 What team behavior patterns are observed?** **RQ2-2 How do team behavior patterns and students' interactions change over time?**	**RQ2-3 How may student interactions and team behaviors affect team performance?**
	Lab 1 meeting to the project working meeting		

Section 2 (Case 2): Team Alpha Case Analysis and Results

Team Alpha collaboration overview.

Performance summary.

Team Alpha performance data is summarized in three parts: individual DST scores, CDR written report scores, and individual course final scores (Table 4-38). The CDR final written report scores were separated at individual and team levels. AF and JR achieved individual DST scores above 90 and LS only received 28 for his performance in DST. In the team's final CDR written report, all members contributed a fair amount of work except LS and the team received 84.2 out of 100 for their the CDR written report. Among all team members, only AF achieved the final course score above 90 and LS had the lowest final score of 74.1 out of 100 compared with his peers.

When evaluating team Alpha's final CDR written report, the instructors found that team Alpha's design was viable and appeared to be robust. However, the overall evaluation feedback suggested that team Alpha's final CDR written report was poorly written and the instructors had difficulties to understand the team's actual work. Other evaluation feedback of the team's CDR report included: accuracy of design was suspected, ambitious scope but lack of execution, and poor design optimization. Important components like design drawing and thermal analysis results were missing in team Alpha's final CDR written report.

Table 4-38

Team Alpha Individual and Team Performance Data Summary

	Members	**DST scores**	**CDR written report scores**	**Course final score**
Team Alpha	AF	93	89	91.6
	MA	84	84	87.9
	JR	91	84	89.0
	AB	85	89	89.3
	LS	28	75	74.1
	Team		**84.2**	

Based on members' perception of peers' efforts and contribution to the team, Alpha students viewed that every member had a fair amount of contribution to the team design project in the first peer assessment. With faculty's feedback suggesting individual members to improve their contribution in the technical areas during team meetings or in volunteering to take on other responsibilities, members either increased their efforts (both MA and AB were perceived by peers to increase their efforts as shown in Table 4-39) or maintained at a similar level of contribution (JR's contribution was perceived at about 19% in the first assessment and 16% in the second assessment) except for LS. LS was perceived to largely decrease his contribution from 22% to 10% in the team project. Alpha members commented that LS put little effort in the meetings, had very minimal contribution in the report, and had bad time planning / management practices, and delivered low quality work, which affected the team grade negatively. LS's decreased, minimal participation in the teamwork may be due to his poor performance in his technical DST area.

Table 4-39

Individual Member Contribution based on Monetary Distribution

Members	**Peer assessment 1 Individual contribution%**	**Peer assessment 2 Individual contribution%**
sMA	19%	24%
JR	19%	16%
AB	18%	23%
LS	22%	10%
AF	/	28%

Peer commented that MA, AB, and AF were major contributors to the final report. While AB appeared sloppy early in the semester, peer commented that he quickly changed his behaviors and became a highly-productive team member. AF joined the team late in the semester and peers valued him as the hardest-working teammate, always taking initiatives, being familiar with every analysis in the report, driving the team to get the work done, and delivering the best quality work.

Meeting profile.

A meeting profile was also created for team Alpha to summarize basic features of the team's selected SameTime meetings (Table 4-40). Basic meeting features contained information of: meeting dates, meeting duration, total word counts, meeting purposes, observed / scheduled tasks, and completion status. Different from team Gamma in which every selected Gamma meeting contained a meeting agenda, team Alpha did not have a regular meeting agenda posted.

The meeting profile data suggested that the team used about 73 minutes and communicated about 5314 words in Lab 1 meeting. In the team's selected project planning meeting, meeting paused for several times due to issues such as frequent voice cut-outs, audio break-downs, or occasions that all members simply paused at the same time. The total minutes of meeting pauses due to reasons unrelated to the meeting tasks (e.g., waiting for the audio to come back normal) was about 34 minutes in total. By deducting the task-unrelated meeting pause time, the actual meeting time was about 42 minutes and students communicated about 4135 words.

In the selected project working meeting, students continued to experience frequent voice cut-outs so the meeting had to pause for several times. The meeting also paused due to situations such as two students left seats to grab water or students focused on editing the presentation slides separately. The total minutes of meeting pauses due to reasons unrelated to the meeting tasks (e.g., waiting for the student to come back to the meeting, waiting for the audio to come back normal) was about 13 minutes. By taking these task-unrelated meeting pauses out, the project working meeting actually ran for about 104 minutes and students communicated about 6312 words including content exchanged both verbally and in chat.

As noted above, the team had different purposes for every selected meeting. Meeting agenda was only observed in team Alpha's selected planning meeting; therefore the description of meeting purposes, scheduled tasks, and completed tasks in the meeting profile (Table 4-36) was based on the observation of the team's meeting recordings.

In response to research question 2 regarding team behaviors, data suggested that team Alpha did not complete scheduled tasks within the meeting period. Technology normalization was not regularly conducted and discussion of routine tasks was not commonly observed. The team either scheduled another meeting to work on unfinished tasks (in Lab 1 meeting) or volunteered for unfinished work (in selected project planning and working meetings). Members usually finished tasks after meeting and shared their work through team space in AIDE.

Table 4-40

Team Alpha's Meeting Profile

Meeting Date	Duration	Word Counts	Observed Meeting purpose	Scheduled/Observed tasks	Completed tasks
Sept. 12 (Lab 1 meeting)	About 73 minutes	5314	To complete the survival on the moon task in Lab 1	▪ Technology normalization ▪ Completing the lab 1 task ▪ Volunteering /delegating responsibilities for routine tasks	Completed technology normalization and the ranking and rationales of top 5 items No discussion was observed for routine tasks
Oct. 5 (selected project planning meeting)	About 76 minutes (actual meeting time: 42 minutes)	4135	To establish project meeting schedules and plan to PDR	▪ Free-time scheduled o Decide a good time to have meetings o Decide how the meeting should be organized (weekly or differently each week) ▪ Team organization o Assign titles for each member o Determine how is in charge of writing minutes ▪ Plan to PDR o Figure out and post: WBS[7], Deadline calendar, and deliverables o Delegate tasks if necessary ▪ Anything else	Decided regular meeting dates and time, delegation of routine tasks for this and the next meeting No discussion regarding 'assign titles for each member' Left WBS, deadline calendar, and deliverables to LS as his after-meeting tasks
Nov. 6 (selected project working meeting)	About 117 minutes (actual meeting time: 104 minutes)	6312	To modify the PDR presentation slides	▪ Modifying the PDR presentation slide by slide	Not completed. JR and GA decided to do a run through and work out more details after the meeting

Quantitative evaluation results.

Interdependence rating scores were calculated for every team Alpha's selected SameTime meeting (see Table 4-41 below). The team's interdependence score maintained at 74% in the first two selected meetings and increased about 8% in the selected project working meeting. The

[7] WBS stands for work breakdown structure

average interdependence score is about 76.3%. Overall, team Alpha's behavioral interdependence maintained at a moderate level, implying that Alpha students may demonstrate behaviors that challenged the establishment of interdependence among them. Inapplicable or unobservable items which were excluded in the rating process were listed and reasons for item exclusion were explained in the table.

Table 4-41

Team Alpha Interdependence Rating Scores

Selected SameTime Meetings	**Interdependence Rating**	**Interdependence Score**	**Items not included**
Sept. 12 (Lab 1 meeting)	37 out of 50	74%	#10: team participants considered the nature of the tasks, individual resources, and fields of expertise when they negotiated about task division #12: a working schedule/agenda was set up (e.g., due dates for each task) <u>Reasons that these items were excluded in the rating and observation process</u>: the project had not started yet and a few team activities had not emerged at this point
Oct. 5 (selected project planning meeting)	34 out of 46	74%	#11: Team participants checked the team's progress #12: Team participants checked each individual's progress #13: Team had contingency plan(s) to cope with time constraints and to ensure a timely and orderly solution to the given problem #26: Team discussed about criteria to decide and support their final solution <u>Reasons that these items were excluded in the rating and observation process</u>: since the project was still at the project planning stage, no individual responsibilities related to the project were finally decided and little work was done related to the project and the PDR; not observed
Nov. 6 (selected project working meeting)	39 out of 48	81%	#9: The team discussed about sharing regular routine tasks, which include taking meeting minutes, scheduling next ST meeting, saving WB notes, taking course surveys, and writing weekly progress reports #10: A working schedule / agenda for the meeting was set up (e.g., tasks for the meeting, duration of each task) #12: Team participants checked each individual's progress <u>Reasons that these items were excluded in the rating and observation process</u>: not observed
Average		**76.3%**	

Frequency and frequency ratio were calculated for every communicative function identified in team Alpha students' meeting conversations (Table 4-42). In response to research question 2 regarding team behaviors, the average frequency ratio data suggested that team Alpha members were most frequently engaged in *responding, interrogating, informing, suggesting*, and *affective conversations*. The time team Alpha spent on these five activities in the three selected meetings were 58.4% in Lab 1 meeting, 80.7% in the project planning meeting, and 70.0% in the project working meeting.

In Table 4-43, frequency ratio changes between every two selected meetings were calculated. In response to research question 2-2 regarding team behavior changes, data suggested that students showed increased participation in *explaining/elaborating, interrogating,* and *informing* and the increase percentages were more than 4%. Students' participation in *reasoning* and *agreeing* decreased for more than 4.0% from Lab 1 to selected project working meeting. *Interrogating* was one major activity that team Alpha students frequently participated in and also showed a consistently increasing trend across the three selected meetings.

Table 4-42

Team Alpha's Communication Function Frequency Distribution and Average Ratio

Comm. Functions	Frequency _ Lab 1	Frequency % _ Lab 1	Frequency _ Project Planning	Frequency % _ Project Planning	Frequency _ Project Working	Frequency % _ Project Working	Average Frequency %
Responsive	74	23.4%	64	23.3%	119	24.4%	23.7%
Interrogative	54	17.1%	51	18.5%	111	22.7%	19.5%
Informative	34	10.8%	68	24.7%	74	15.2%	16.9%
Suggestive	29	9.2%	25	9.1%	41	8.4%	8.9%
Affective	28	8.9%	23	8.4%	42	8.6%	8.6%
Explanative / Elaborative	1	0.3%	7	2.5%	42	8.6%	3.8%
Reasoning	29	9.2%	2	0.7%	4	0.8%	3.6%
Organizational	14	4.4%	5	1.8%	21	4.3%	3.5%
Agrees	17	5.4%	5	1.8%	4	0.8%	2.7%
Argumentative	12	3.8%	4	1.5%	6	1.2%	2.2%
Affirmative	4	1.3%	3	1.1%	11	2.3%	1.5%
Repetitive	1	0.3%	6	2.2%	9	1.8%	1.4%
Summative	3	0.9%	5	1.8%	1	0.2%	1.0%
Disagrees	6	1.9%	2	0.7%	0	0.0%	0.9%
Talk aloud	5	1.6%	1	0.4%	0	0.0%	0.6%
Evaluative	1	0.3%	3	1.1%	2	0.4%	0.6%
Confirmative	2	0.6%	1	0.4%	1	0.2%	0.4%
Read aloud	2	0.6%	0	0.0%	0	0.0%	0.2%
Total	**316**	**100.0%**	**275**	**100.0%**	**488**	**100.0%**	**100.0%**

Table 4-43

Team Alpha's Communication Function Frequency Distribution and Change

Comm. Functions	**Frequency% _ Lab 1**	**Frequency% _ Project Planning**	**Frequency% _ Project Working**	**ΔFrequency% (Lab1 - Project Planning)**	**ΔFrequency % (Project Planning - Project Working)**	**ΔFrequency% (Lab1 - Project Working)**
Explanative / Elaborative	0.3%	2.5%	8.6%	2.2%	6.1%	**8.3%**
Interrogative	17.1%	18.5%	22.7%	1.5%	4.2%	**5.7%**
Informative	10.8%	24.7%	15.2%	14.0%	-9.5%	**4.4%**
Repetitive	0.3%	2.2%	1.8%	1.9%	-0.4%	1.5%
Affirmative	1.3%	1.1%	2.3%	-0.2%	1.2%	1.0%
Responsive	23.4%	23.3%	24.4%	-0.1%	1.1%	1.0%
Evaluative	0.3%	1.1%	0.4%	0.8%	-0.7%	0.1%
Organizational	4.4%	1.8%	4.3%	-2.6%	2.5%	-0.1%
Affective	8.9%	8.4%	8.6%	-0.5%	0.2%	-0.3%
Confirmative	0.6%	0.4%	0.2%	-0.3%	-0.2%	-0.4%
Read aloud	0.6%	0.0%	0.0%	-0.6%	0.0%	-0.6%
Summative	0.9%	1.8%	0.2%	0.9%	-1.6%	-0.7%
Suggestive	9.2%	9.1%	8.4%	-0.1%	-0.7%	-0.8%
Talk aloud	1.6%	0.4%	0.0%	-1.2%	-0.4%	-1.6%
Disagrees	1.9%	0.7%	0.0%	-1.2%	-0.7%	-1.9%
Argumentative	3.8%	1.5%	1.2%	-2.3%	-0.3%	-2.6%
Agrees	5.4%	1.8%	0.8%	-3.6%	-1.0%	**-4.6%**
Reasoning	9.2%	0.7%	0.8%	-8.4%	0.1%	**-8.4%**
Total	**100.0%**	**100.0%**	**100.0%**			

In sum, a moderate level of behavioral interdependence was formed among team Alpha students. In response to research question 2 regarding team behaviors, the team participated most frequently in the behaviors of: interrogative, responsive, informative, suggestive, and affective; among which, students' participation in interrogation showed a consistently increasing trend across the three meetings. Besides, the team's participation in explanative and elaborative conversations grew about 8.3% in the project working meeting since their initial teamwork on Lab 1 task. In following paragraphs, team Alpha students' behaviors in communication, planning, and decision-making were reported in turn. Individual behaviors' association to team behaviors, team collaboration, and team performance were also examined. Attention was further spared on exploring potential reasons to explain a sudden increase in the team's behavioral interdependence in the selected project working meeting.

Communication.

Collaboration flow (turn-taking): interrupting factors.

In response to research question 1 regarding individual behaviors in turn-taking, Alpha students were observed to be able to maintain their conversation flow and handed over turns by asking questions or naming a specific person. However, the team's collaboration flow and conversational transitions were frequently interrupted by technology issues, disruptive behaviors, and personal matters.

Alpha students often experienced technology issues such as voice cut-outs and technology break-downs. Such technology issues lasted from several seconds to 2 minutes and resulted in students' inaudible voices and paused communication. Paused communication was also observed in situations when (1) two students simply stopped talking at the same time and (2) students left their seats for personal matters (e.g., GA was observed to leave his seat for about 9 minutes to grab water). During such periods, rest of the team members simply stopped talking and waited for the person to come back.

In response to research question 1-2 regarding how individual behaviors may affect team performance, frequent meeting / communication pauses challenged students to have smooth turn-taking and resulted in broken conversations (e.g., a 8-minute conversation was observed to be paused for four times which added up to 6 minutes), extended meeting duration, and delayed work progress. When the meeting continued for a certain period without much progress due to frequent meeting pauses, members may become frustrated and tired. Their motivation of continuing the task can be discouraged and their attention to the work quality can also be decreased (see an example shown in Table 4-44).

Table 4-44

An Example of Decreased Working Motivation _ Alpha Project Planning Meeting

Participants	Conversation transcripts	Comm. Channels
GA	By the way, I'm looking at the team dynamic comparison from that lecture, I think we need to move on to informed pessimism as quickly as possible so there is everybody pessimistic right now, let's get pessimistic.	
AB	We're screwed man. The PDR is not even going to even get done by December.	
GA	Well, we've got another week.	
AB	we're screwed	In chat

Collaboration flow: response rates and responding behaviors.

In addition to team Alpha's communication issues described above, the team's response rates to answer questions and suggestions were also examined as an important indicator to evaluate the team's communication. In response to research question 1 regarding individual responding behaviors, table 4-45 and 4-46 showed the team's response rates in the three selected meetings. Average response rate was also calculated by averaging the response rates in the three meetings.

Table 4-45

Team Alpha's Response Rates to Answer Questions

	#Questions	**#direct responses**	**# indirect responses**	**#Unanswered questions**	**Question-Response Rate**
Lab 1	54	49	3	2	96.3%
Project Planning	51	43	2	6	88.2%
Project Working	111	88	8	15	86.0%
Total/Average	**216**	**180**	**13**	**23**	**89.4%**

Table 4-46

Team Alpha's Response Rates to Answer Suggestions

	#Suggestions	**#direct responses**	**#indirect responses**	**#No responses**	**Suggestion-Response Rate**
Lab 1	29	22	0	7	75.9%
Project Planning	25	20	0	5	80.0%
Project Working	41	33	3	5	88.0%
Total/Average	**95**	**75**	**3**	**17**	**82.1%**

Response rate data suggested that Alpha students' response rate to answer questions is consistently decreasing across the three selected meetings. The average response rate to answer questions is about 89.4%. The decreasing response rates implied that several questions were ignored during the team conversations. Although students' responding-to-suggestion behaviors continued to grow, the average response rate to answer suggestions is about 82.1%, suggesting that several ideas were ignored and not responded during the team conversations.

Observation data further confirmed the team's moderate response rate that several suggestions and questions were ignored during the team discussion. These ignored suggestions or questions were usually observed in situations when: (1) students brought in a new item into the meeting discussion without finishing the previous item and (2) use of two communication channels distracted students' focus on one single topic in either of the channels. When students communicated verbally and in chat simultaneously, information communicated through both channels sometimes distracted students' attention from focusing on one single topic in either channel; therefore some information, questions, or suggestions were ignored.

Majority of the questions were responded with direct answers. For indirectly responded questions, Alpha students asked more questions to clarify their understanding of the original question instead of providing a direct answer, which is similar to Gamma students' behaviors (an exemplary case with indirectly-responded questions is shown in Table 4-47). In this example, GA asked whether the magnetic compass functioned the same way as it did on Earth. Instead of giving a specific answer, JR asked a further question to confirm that there was actually a magnetic field on the Moon. GA then explained his thoughts of the magnetic field and its work mechanism on the Moon. LS confirmed GA's explanation. JR's question in his indirect response was important because it revealed that JR also had the question regarding the Moon's magnetic field and its work mechanism. With GA's further explanation and LS's confirmation, JR's confusion should be resolved. Through this short conversation, JR's knowledge regarding how the Moon's magnetic field works could be enriched and his enriched knowledge can further enable him to provide stronger rationale to explain the low ranking of the magnetic compass in this task.

Table 4-47

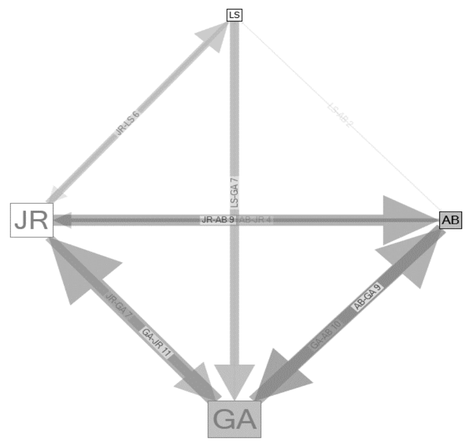
An Example of Indirectly Answered Questions _ Alpha Lab 1

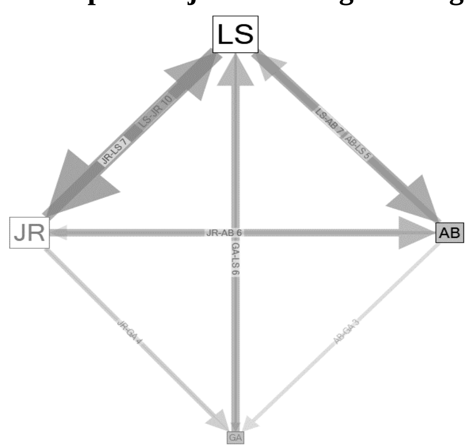
Line No.	Participants	Conversation transcripts
1	GA	...anybody know the north and south poles the moon are magnetized weird... whether magnetic compass function the same way?
2	JR	Had a magnetic field doesn't it?
3	GA	You know how there's polar north and there's uhm... where it kind of shifted off of one another?
4	LS	Right.

Alpha students' responding behaviors to questions and suggestions in the three selected meetings was also mapped out by using social network analysis (Figure 4-4).

In response to research question 2-1 regarding member responsive interactions, the figures showed that major response-to-questions / suggestions interactions happened among AB, JR, and GA in Lab 1 meeting. This pattern changed in the team's selected project planning meeting and JR and LS became major respondents. AB asked several questions in the first two meetings but he seemed withdrawing his role in either asking or responding questions /

suggestions in the team's selected project planning meeting. In selected project working meeting, the response interaction pattern changed again. Major response-to-questions / suggestions interactions happened between GA and JR and between JR and AF. Responses from AB and LS were minimal and majority of responsive interactions occurred among University A students.

Responsive Interaction Alpha Lab 1 Meeting	**Edge labels reflecting responsive behavior frequencies**
	AB-GA 9 AB-JR 4 AB-LS 2 GA-AB 10 GA-JR 11 GA-LS 2 JR-AB 9 JR-GA 7 JR-LS 6 LS-AB 2 LS-GA 7 LS-JR 4

Responsive Interaction Alpha Project Planning Meeting	**Edge labels reflecting responsive behavior frequencies**
	AB-GA 4 AB-JR 4 AB-LS 6 GA-JR 2 GA-LS 7 JR-AB 7 JR-GA 5 JR-LS 9 LS-AB 9 LS-GA 3 LS-JR 12

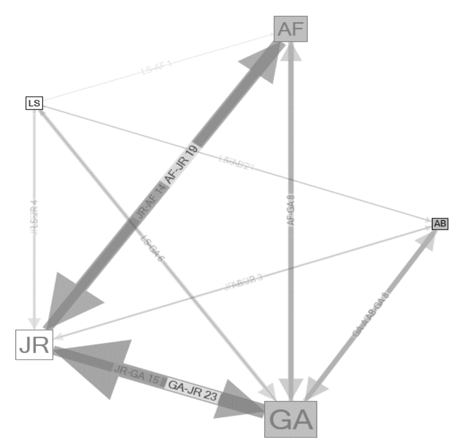
Responsive Interaction Alpha Project Working Meeting	**Edge labels reflecting responsive behavior frequencies**
	AB-GA 8 AB-JR 3 AB-LS 1 AF-GA 8 AF-JR 19 GA-AB 7 GA-AF 7 GA-JR 23 GA-LS 2 JR-AB 2 JR-AF 14 JR-GA 15 JR-LS 1 LS-AB 2 LS-AF 1 LS-GA 6 LS-JR 4

Figure 4-4. Responsive behaviors to questions and suggestions _ Alpha

Mutual participation.

Overview.

Overall, students focused attention on solution-relevant information and showed collaboratively oriented social interactions. In response to research questions 1 regarding individual behaviors and individual behavior changes in meeting participation, data implied that students had mutual participation in the meetings and their participation was relatively even in Lab 1 and became more even in the project planning meetings. Student participation in the project working meeting did not follow the same pattern observed in Lab 1 and project planning meetings. In the project working meeting, student participation was mutual but not even among members (see the three participation status tables 4-48, 4-49, and 4-50 below). In the project working meeting, JR and GA were more verbal than other members in the team, which is probably because JR and GA were to represent the team to do the PDR presentation. AF was engaged in the first part of the meeting but he left early to work on his other projects. AB did not participate in the conversations at the first half of the meeting until the team discussed his part of the slides.

Table 4-48

Students' Participation Status _ Alpha Lab 1

Participants	Frequency	Frequency%	Word Counts	Word Counts%
AB	64	23.8%	896	16.9%
GA	97	36.1%	2185	41.1%
JR	71	26.4%	1444	27.2%
LS	37	13.8%	789	14.8%
Total	**269**	**100.0%**	**5314**	**100.0%**

Table 4-49

Students' Participation Rates _ Alpha Project Planning

Participants	**Frequency**	**Frequency%**	**Word Counts**	**Word Counts%**
AB	59	24.8%	678	16.4%
GA	56	23.5%	1103	26.7%
JR	61	25.6%	903	21.8%
LS	62	26.1%	1451	35.1%
Total	**238**	**100.0%**	**4135**	**100.0%**

Table 4-50

Students' Participation Rates _ Alpha Project Working

Participants	**Frequency**	**Frequency%**	**Word Counts**	**Word Counts%**
AB	32	8.1%	341	5.4%
AF	56	14.2%	900	14.3%
GA	150	38.2%	2851	45.2%
JR	112	28.5%	1802	28.5%
LS	43	10.9%	418	6.6%
Total	**393**	**100.0%**	**6312**	**100.0%**

Across the three meetings, Alpha students appeared to have inconsistent participation patterns. Accordingly, their participatory roles did not follow a consistent pattern from Lab 1 meeting to the selected project working meeting (see Table 4-51). For instance, AB was initially one of the main students to ask questions (AB *N*=18/54 in Lab 1, *N*=11/51 in project planning), share information (AB *N*=12/34 in Lab 1, *N*=16/68 in project planning), and have affective conversations (AB *N*=10/28 in Lab 1, *N*=7/23 in project planning) in Lab 1 and project planning meetings. He withdrew his participatory role in these conversations in the selected project working meeting as his overall participation in this meeting dropped markedly.

Table 4-51

Team Alpha Students' Participation in Different Communication Functions

Case 2: Team Alpha	Lab 1				Project planning				Project working					
Comm. Functions	**AB**	**GA**	**JR**	**LS**	**AB**	**GA**	**JR**	**LS**	**AB**	**AF**	**GA**	**JR**	**LS**	**N**
Responsive	15	25	22	12	13	8	19	24	11	29	38	30	11	257
Interrogative	18	17	15	4	11	11	19	10	10	20	31	44	6	216
Informative	12	12	8	2	16	18	23	11	2	6	33	27	6	176
Suggestive	5	12	4	8	7	6	2	10	1	8	22	7	3	95
Affective	10	8	4	6	7	3	5	8	3	2	17	8	12	93
Explanative /Elaborative	---	---	1	---	3	1	2	1	2	3	26	8	3	50
Organizational	3	11	---	---	1	3	---	1	1	3	10	6	1	40
Reasoning	1	13	10	5	1	---	1	---	---	---	2	2	---	35
Agrees	6	4	5	2	1	2	2	---	---	1	---	3	---	26
Argumentative	5	1	4	2	---	---	---	4	1	---	2	2	1	22
Affirmative	2	---	1	1	---	1	1	1	2	---	6	3	---	18
Repetitive	---	---	1	---	2	1	1	2	---	1	5	2	1	16
Summative	---	2	1	---	2	1	1	1	---	1	---	---	---	9
Disagrees	1	3	2	---	1	---	1	---	---	---	---	---	---	8
Evaluative	---	1	---	---	---	3	---	---	---	---	1	---	1	6
Talk aloud	---	4	1	---	---	1	---	---	---	---	---	---	---	6
Confirmative	1	1	---	---	---	1	---	---	---	---	1	---	---	4
Read aloud	---	1	1	---	---	---	---	---	---	---	---	---	---	2

Participation in task-unrelated behaviors.

In response to research question 1 regarding individual behaviors in meeting participation, data suggested that team Alpha spent a certain amount of their meeting time on joking or goofing around. There were several occasions in which they introduced jokes in their discussions. Sometimes, it was confusing whether they were joking or proposing a solution (see an example in Table 4-52 below). In the example, when the team was discussing how to use oxygen tanks and transport them, LS suggested attaching AB to the rope. It was not clear whether LS was joking or actually suggesting a real solution because the team was then actually engaged in a brief discussion regarding LS's suggestion by proposing the idea of tying AB to the rope. Although the jokes may imply a good relationship among all members, it did distract the team's attention from developing a doable solution by following the task requirement. At the end, AB drew the team's attention back by reminding that the task required all members to stay together.

Table 4-52

Jokes in the Meeting _ Alpha Lab 1

Line No.	Participants	Conversation transcripts
1	LS	Alright I got the great idea. We're going to attach AB to the twenty meters of nylon rope and we're going to do a little twirl around, you know, and then filming and see if we can find the raft on the space ship.
2	JR	Attach a what?
3	AB	Attach me.
4	JR	Oh AB.
5	GA	with that, that could really work, especially if we give him the oxygen tank and we knock off the head so it literally becomes a... slingshot and you kind of just have to let go right at the right point, which we as engineers on the moon will calculate. We won't have any pencil and paper on the moon.
6	LS	We can uhm, for pencil and paper we can just use our foot and the moon rock that will work. Like writing in dirt.
7	GA	If we miss with AB, we're screwed…
8	AB	I missed that.
9	GA	We lose the AB… AB?
10	AB	No I'm still here, I'm still alive. Maybe you could give me the signal flares.
11	GA	That works. Wait we should keep one. Actually this is a good idea because if we stay by the crashed ship, just fling you, then we'll have all this stuff, I won't need to carry any of it with us. You'll be stuck alone of course.
12	AB	Really? the other problem with this plan is that your directions say that we have to stick together.

Jokes distracted students' attention away from the tasks (see an example in Table 4-53). In the project working meeting, when AF and JR were discussing how to present the dimension data of the plate, both AF and JR agreed to use the professor's dimension graphic in their DST training. GA informed the team that he was disconnected but no response from the other members. When JR was uploading the professor's presentation slides into the Whiteboard, GA joked in chat about the number of the professor's slides and said he must be sleeping all day. JR then responded him verbally. GA's joke distracted JR's attention from the task.

Table 4-53

Goofing in the Meeting _ Alpha Project Working

Line No.	Participants	Conversation transcripts	Comm. Channels
1	AF	Do you think we should keep this one? I feel like this might just have information in it, like in the design approach.	
2	JR	I don't know if it's a horrible idea to have it in there, I just like the one we used in our DST, like Davidson gave us one. Let me see if I can find it.	
3	GA	I guess I did disconnect	in chat
4	GA	I wasn't getting any A/V or ppt	in chat
5	JR	Would it be not allowed to just put this picture right there?	
6	AF	I think you can, I've seen other groups that have the same picture in there so I'm sure its fine.	
7	GA	whoa! When did we get to 30 slides!	in chat
8	GA	I'm been in class or nap all day	in chat
9	GA	Lol	in chat
10	GA	whoo hoo, my slide	in chat
11	JR	Oh that would be embarrassing.	

Students were also observed to be involved in games or task-unrelated side talks. For instance, LS and AB had a side talk in chat about AB's job interview during the project working meeting. Additionally, data suggested that students did not keep their sitting environments free of distractions and different sounds were heard in the middle of meeting discussions, such as the traffic noise from streets or sounds from people zipping bags, unlocking the door, and people entering the room. These external noises may also have distracted students' attention to tasks.

Participation in affective conversations.

In response to research question 1 regarding individual behaviors and individual behavior changes in meeting participation, data suggested that Alpha students involved in affective conversations at a relatively high frequency. The affective conversation data shown in Table 4-54 listed team Alpha students' participation rate and percentage of time spent on the affective conversations in the three meetings. As described above, affective conversations were one of the major activities that team Alpha students were engaged in. The time students spent on affective conversations did decrease from Lab 1 meeting to the project working meeting while the students' participation rate in affective conversations stayed consistently across the three meetings. As described above, although affective conversations may help build a close relationship among members, these task-unrelated affective conversations consumed the team's actual working time as well as distracted the team's attention from tasks. The Table 4-55 showed some examples of affective conversations in the three selected meetings. As data showed, team Alpha's affective conversations were used for greeting, making farewell, commenting on peer's work, commenting on the team's progress, showing appreciation, showing apology, and joking. Different from the affective conversations carried by team Gamma students, a large portion of team Alpha's affective conversations were task-unrelated.

Table 4-54

Affective Conversation Distribution in the Three Selected Meetings _ Alpha

	Frequency	**Frequency%**	**Word Counts**	**Word Counts%**
Lab 1	28	8.9%	272	5.1%
Project Planning	23	8.4%	160	3.9%
Project Working	42	8.6%	196	3.1%

Different from affective conversations communicated in Lab 1 meeting which happened throughout the meeting, the affective conversations in the project planning and working meetings were mostly observed at the beginning or toward the end of the meeting. Besides, majority of the affective conversations were communicated in chat in these two later meetings (e.g., 79% of the affective conversations in the project working meeting was communicated in chat).

Table 4-55

Affective Conversations _ Alpha Lab 1

No.	Participants	Conversation transcripts	Comm. Channels	Affective Comm. Functions
Example 1	GA	That's way harder than what it should have been.		Affective: express the feeling about the task
Example 2	GA	We uhm, here's what we do, take the guns, we shoot Justin and Louis, that way we have more food for each of us and we we'll have water for each of us. Otto and myself are going to make the... 250 mile trek and... you guys just got to man up and take them.		Affective: joked about solutions
Example 3	AB	I guess you can see where I kind of stand about the crazy plan.		Affective: expressed preference on solutions
Example 4	JR	Good night, see you guys.		Affective: made farewell
Example 5	LS	Excellent.		Affective: commented on teammate's work
Example 6	JR	Thanks.		Affective: showed appreciation
Example 7	JR	Sorry		Affective: showed apology
Example 8	AB	I suggest we play tic tack toe to determine some of these		Affective: suggested playing games
Example 9	LS	The, our design studio is one of the nicest rooms on campus, we've got a whole view of the whole campus and nobody comes in here. It's marvelous		Affective: commented on the working environment
Example 10	AB	We're screwed man. The PDR is not even going to even get done by December.		Affective: joked about the team's progress
Example 11	LS	the dog is chasing the cat.	in chat	Affective: joked about LS's pets
Example 12	GA	I'm been in class or nap all day	in chat	Affective: goofing
Example 13	JR	I think that is a comment on our productivity.		Affective: joked about the team's low productivity

As a summary, team Alpha students contributed to the team collaborative efforts at a moderate level. In response to research question 1 regarding individual behaviors in communication and question 1-2 regarding how individual behaviors may affect performance, students' behaviors contributed to, as well as challenged, each other's and the team's success to maintain a fluent communication flow and the formation of interdependence in their communication. Such student behaviors included: (1) use of chat to complement verbal conversations during technology break-downs which sometimes resulted in ignored messages and not-responded questions, (2) introduction of a new topic without finishing the discussion of the previous item, which resulted in ignored information and un-responded questions, (3) no regular technology-normalization and sometimes left technology issues unsolved which might be the main reasons for frequent voice cut-outs, (4) leaving seats for personal matters which caused communication pauses, (5) introduced task-unrelated jokes and spent a certain amount of time on task-unrelated affective conversations but were not able to quickly draw attention back to tasks, and (6) did not keep their sitting environment quiet and background noises were often heard during meeting discussions.

In response to research question 2 regarding team behaviors and team behavior changes in communication, data suggested that the team was consistently observed (1) to have frequent meeting pauses due to reasons such as frequent voice cut-outs or students' personal matters, (2) to have moderate levels of response rates to questions and suggestions and several questions and suggestions were not responded or ignored, (3) to often have task-unrelated affective conversations and background noises which may distract students' focus on tasks, and (4) not to have a consistently even participation rate among students.

In response to research question 2-3 regarding how team behaviors may affect performance, data suggested that situations, including frequent meeting pauses, ignored questions and suggestions, and interrupted communication flow, resulted in delayed meeting progress, extended meeting duration, and decreased meeting productivity, and further caused frustration and discouraged working morale.

Comparing the two teams, team Alpha and Gamma seem to share few similarities and present more differences in students' communication behaviors. Similar to team Gamma, Alpha students were able to maintain their conversation flow during the meeting discussion. However, different from team Gamma who was observed to maintain smooth conversation flow and turn-taking, Alpha students encountered frequent meeting pauses and some of which were caused by individual student behaviors such as leaving seats for personal matters. Frequent meeting pauses challenged Alpha students to have smooth turn-taking and resulted in broken conversations, extended meeting duration, delayed meeting progress, and discouraged working morale.

Other similarities and differences include: (1) similar to Gamma students, Alpha students were observed to ask for clarification when they did not understand peers' original questions, (2) different from team Gamma who had 100% response rates, team Alpha's response rates to answer questions were decreasing across the three meetings, and (3) different from Gamma students whose affective conversations were mainly task-related, a large portion of team Alpha's affective conversations were task-unrelated, which included jokes, games, and side-talks. On average, affective conversations distracted Alpha students' attention away from tasks and consumed about 4.03% of team Alpha's meeting time. In contrast, affective conversations merely consumed about 1% of team Gamma's meeting time and Gamma students quickly drew their attention back to the design tasks.

Planning.

Task planning and management.

In response to research question 1 regarding individual behaviors in task management, descriptive statistics of organizational conversations were first reported in order to offer readers a general impression of team Alpha students' task management behaviors (Table 4-56 and 4-57).

Based on the descriptive statistics, team Alpha students' participation in organizational conversations fluctuated across the three selected meetings and does not show a consistently changing pattern. The team participated rate in organizational behaviors is about 4.4% in Lab 1 meeting, and decreased to 1.8% in the project planning meeting, and increased back to about 4.3% in the project working meeting. On average, team Alpha's participation rate in organizational conversations is about 3.5% and consumed about 2.8% of meeting time.

According to Table 4-53, GA seemed playing a major role in organizing team discussions. AB and LS also contributed to organizational activities at a certain level and their participation in organizational conversations decreased dramatically in the project working meeting.

Table 4-56

Organizational Communicative Conversations by Meeting _ Alpha

Organizational Communicative Conversation Frequency & Word Counts by meeting				
Selected Meetings	**Frequency**	**Frequency%**	**Word Counts**	**Word Counts%**
Lab 1 meeting	14	4.4%	245	4.6%
Project Planning Meeting	5	1.8%	22	0.5%
Project Working Meeting	21	4.3%	211	3.3%
Total/Average	**40**	**3.5%**	**478**	**2.8%**

Table 4-57

Organizational Communicative Conversations by Meeting and Participants _ Alpha

Organizational Communicative Conversation Frequency% by meeting and participants			
Participants	**Frequency% _ Lab 1**	**Frequency% _ Project Planning**	**Frequency% _ Project Working**
AB	21.4%	20.0%	4.8%
AF	/	/	14.3%
GA	78.6%	60.0%	47.6%
JR	0.0%	0.0%	28.6%
LS	0.0%	20.0%	4.8%

Team Alpha students used organizational conversations served different organizational purposes which include (see some examples listed in Table 4-58): (1) to organize the team's behaviors (the first and second examples), (2) to manage individual student's behavior or actions (the third, fourth, and fifth examples), and (3) to suggest individual or the team's future behavior or actions (the sixth and seventh examples).

Table 4-58

Exemplary Organizational Conversations _ Alpha Lab 1

No.	Participants	Conversation	Comm. Channels	Organizational Comm. Functions
Example 1	GA	Okay so everybody gets to write or type it all then into a square uh, go from there.		Organizational: organized the team's behaviors by suggesting two different input methods
Example 2	GA	Alright so now we have to compare and discuss the single team rankings. .		Organizational: directed the team's actions by suggesting to discuss the team ranking
Example 3	GA	Justin you got to unmute yourself.		Organizational: suggested JR to unmute
Example 4	LS	Go ahead		Organizational: asked another student to speak first
Example 5	JR	LS I guess is the moderator, if you grant the permission that everyone can take the control but last time we didn't really do that cause just got… but if you want to, like I am sharing it from here		Organizational: directed LS's behavior
Example 6	AB	Yeh so just save it to the, I think in the AIDE thing you can put it on the drop box without submitting it so once you do that, just like shoot each of us an email and we'll take a look at it and confirm it.		Organizational: suggested GA's future action
Example 7	GA	we'll figure it out	In chat	Organizational: suggested future mutual actions

To complement quantitative data, observation data suggested that team Alpha students' problem-solving process is unstructured. Planning actions were seldom noticed. In response to research question 1 regarding individual behaviors in task management, students were frequently observed to randomly start a new topic without finishing previous topics. Table 4-59 is showing team Alpha's team problem-solving of moon-survival item ranking task in Lab 1 meeting. After students completed individual rankings, GA called students for team ranking discussion. AB and GA started the discussion of how the team should begin with the team ranking based on the task requirements. It sounded that AB and GA reached some agreement on starting from "Number 1 ranking" item so GA started questioning LS's ranking of oxygen (Line No. 92). After listening to GA's reasoning, LS agreed to rank oxygen as the number 1 item. Suddenly, AB jumped in and questioned JR's ranking of the signal flares. JR provided his reasoning (Line No. 100). AB did not give a definite response nor did he provide any sound reason to argue against JR. He only responded to LS with "I don't think it really matters" (Line No. 103). No further discussion regarding the signal flares continued and no decision was made regarding the team ranking of the signal flares. AB then jumped into another new item and started questioning why all team members ranked the pistol at the bottom (Line No. 104). AB asked the question by joking that "Are we going to fight aliens or something" (Line No. 105). From Line No.106 to 124, the team continued their discussion on the ranking of pistols and then suddenly switched to the ranking of the box of matches without having a decision on the ranking of pistols (Line No. 122).

Then, after GA and JR's brief discussion of using Excel to calculate average rankings for every given item (Line No. 125-128), AB suddenly brought up water into discussion (Line No. 129). Till this point, the team's selection of items for their team discussion was random. Neither did the team discuss about any working strategies (e.g., ranking from the top or from the bottom) to better organize their ranking discussion.

Table 4-59

Team Alpha's Random Sequence in the Discussion of Ranking Items

Line No.	**Participants**	**Conversation transcripts**	**Comm. Functions**	**Decisions / Agreement**
86	GA	Alright so now we have to compare and discuss the single team rankings. .	Organizational	
87	GA	Okay so now we can only pick the top 5, then we're done. Alright, uhm	Organizational	
88	AB	Don't we have to complete ranking and then rationales for the top 5?	Interrogative	
89	GA	Yeh, some rankings then rationales.	Responsive	
90	GA	But I was just thinking that if they don't have any suggestions on the most	Suggestive	

Line No.	Participants	Conversation transcripts	Comm. Functions	Decisions / Agreement
		efficient way for us to compare these. I think number 1, I mean I think that we should … (inaudible) … and weigh the average... I don't think we're going to get a set of rankings by doing that.		
91	AB	Yeh we'll get close enough and then we can just have one person pick and choose.	Responsive	
92	GA	I guess we can do that, I was thinking that I was kind of curious why Louis put oxygen there as an 8 of priority when the three of us put it at number 1? Louis?	Interrogative	
93	LS	I always thought that the suits would be, would contain enough oxygen as something that would be for purified oxygen that's already in the atmosphere at the moon whatever that is, whatever minimal, I don't know.	Responsive	
94	GA	Uhm, I think the… not an atmosphere so I don't think there's anything, I think you are stuck on your own food supply. Like we're really making this stuff up since it was given as uhm, guidelines.	Reasoning	
95	LS	Okay. I don't know as like I guess we could put it as 1 then, that would be fine.	Agrees	
96	GA	Alright that's cool.	Confirmative	LS agreed with GA and other team members that oxygen should be ranked as #1
97	GA	It's really like we're all shooting in the dark because they don't tell us how much oxygen the suit has, they don't tell us…	Reasoning	
98	AB	Justin why did you put signal flares as 14?	Interrogative	
99	GA	Justin you got to unmute yourself.	Organizational	
100	JR	Actually I had that back Greg. Now I wasn't thinking they'd be very useful with that oxygen.	Responsive	

Line No.	Participants	Conversation transcripts	Comm. Functions	Decisions / Agreement
101	AB	So I guess we’re assuming, or I was probably assuming then that’s there were signal flares.	Reasoning	
102	LS	Uh, there were no signal flares.	Informative	
103	AB	I don’t think it really matters.	Affective	
104	AB	Okay uhm, I guess all of us put the pistols at the bottom.	Informative	
105	AB	Are we going to fight aliens or something?	Interrogative	
106	JR	I didn’t put them all the way at the bottom…	Responsive	
107	JR	They wouldn’t fire without oxygen, no I’m like, yeh you know, whichever and propulsion, I don’t know.	Reasoning	
108	GA	Actually that’s a pretty darn good idea. I wasn’t thinking of that before.	Evaluative	
109	GA	Did you just keep firing off rounds and?	Interrogative	
110	JR	Yeh…	Responsive	
111	LS	First I think the pistols are a contingency plan is what they are.	Suggestive	
112	JR	Yeh like ah.	Responsive	
113	GA	Suicidal.	Affective	
114	LS	If you can carry them with oxygen doesn’t look like it’s going to last all of us, blow away, you know.	Reasoning	
115	GA	I don’t know... that’s a good point.	Agrees	
116	LS	I thought that we were going to do is fill the life raft up with oxygen and then make our own air balloon with the oxygen tanks and we could float away.	Suggestive	
117	AB	But then again, there isn’t any atmosphere.	Responsive	
118	GA	We could do a calculation… a rocket made out of a… raft with oxygen in it…or engineered.	Suggestive	
119	GA	Alright, there is another idea, if we’re all in for 15 or 14 for the box of matches for every one of us. So should we put the match at 15 or the pistols at 15?	Suggestive	
120	AB	I don’t know I’m trying,	Responsive	
121	AB	I’m just the idea of pistols as a propulsion, maybe we could even fire them at the oxygen tanks and get big bang and get somewhere.	Suggestive	
122	GA	So I guess the matches' gonna go 15?	Interrogative	
123	JR	I can agree with that.	Responsive	

Line No.	Participants	Conversation transcripts	Comm. Functions	Decisions / Agreement
124	AB	Yeh that's fine.	Responsive	AB and JR agreed with GA that the ranking of matches should be #15
125	GA	It should be done in Excel. Then we can have the total for us at the bottom already. I should all be doing that now copy this all into Excel or you guys can talk about the ones in the middle. I mean you aren't taking as much power as I did with totals... I get into medical? totals with middle stuff because I'm pretty sure the middle are going to be the hardest ones so extremes are going to be easy for us	Suggestive	
126	JR	Why do we need average	Responsive	
127	JR	I don't know what you mean?	Interrogative	
128	GA	It's just, when I think of speed if we could get a rated average, get a rough idea of what the generally important ones were.	Responsive	
129	AB	So you guys think water is important?	Interrogative	
130	LS	Yeh	Responsive	
131	AB	What did you put as 2?	Interrogative	
132	AB	You put signal flares above the water.	Informative	
133	LS	Water, I think water sounds like a bad idea	Responsive	
134	LS	cause if you guys are going to have to go to the bathroom in your suits, that's gonna…	Reasoning	
135	GA	I agree with you, it's going to be messy but if we are also walking 250 miles, we're going to need hydration no matter what.	Argumentative	
136	JR	Nah, I'd like to keep that till the end.	Disagrees	

Such random discussion sequence was observed for several times. In response to research question 1-2 regarding how individual behaviors may affect team performance, Alpha students' random discussion sequence of bringing new topics without finishing previous items resulted in information or questions being ignored (as described above). Such random discussion sequence also distracted members' attention and prevented the team to stay focused on having a continuous, complete discussion of one task item. Take the following case in Table 4-60 for example. Before the team reached a conclusion about the ranking of transmitter and signal flares, AB jumped in and informed the team that he did the ranking for the bottom 5 items. Then the meeting paused for about 2 minutes. AB broke the pause by asking JR and GA whether they needed to leave the meeting early. The focus of the team's conversation was changed after the meeting pause. AB's new topic interrupted the team's progress in discussing the rankings of transmitter and signal flares and caused the meeting pause. Then the meeting pause delayed the team from having a continuous, clear argument on the rankings of the transmitter and signal flares.

Table 4-60

An Example of Bringing in Task-unrelated Topic _ Alpha Lab 1

Line No.	Participants	Conversation transcripts
1	AB	What about the transmitter?
2	GA	Uhm, personally I think it doesn't rank in top 5 because that is a confusing topic because if we could radio our exact location to them, I would assume that they won't be able to rescue us according to the directions, yet if we would get within visual distance of the rendezvous site, then magically we will get...
3	AB	Well it says that they can't do an extensive search, I'm sure they could at least do one pass and if we tell them "Ok we're at this location, come by here," then that's it, game over.
4	GA	Yeh I guess that yeh I agree with if that worked, that is a more sensible thing to do, stay at the rendezvous site with all your gear, stay together, have your food, have your water, have your radio transmitter and radio your exact coordinates by a map.
5	JR	Yeh I think the rank to the transmitter if they really limited, I think the range of the flares would probably be a little greater just cause you can do that and shoot them out, they... flares.
6	AB	I am sorry, You are cutting off
7	JR	I mean I'm not really familiar with the range of flares or the range of radio, uhm but I was thinking like the radio can't go through the moon, but the flares can go around it like around the curvature.
8	AB	Okay
9	LS	You know the other thing is we'll either have a stellar map or solar power FM receiver and since you are going to be day or night out, I don't think we're really going to be able to see any stars, so I think that'd be a trade off.
10	JR	I think they should tell us one way or the other.
11	AB	Uhm, I just... went and labeled 10 to 15, if you guys disagree with that, just let me know, but if not you can at least knock out the bottom five.
Audio PAUSE for about 2 minutes – GA was writing something in red in the ranking table		
12	AB	Don't you guys have to go to class or something?

Management of routine tasks.

In response to research question 1 regarding individual behaviors in managing routine tasks, data suggested that team Alpha students may be not familiar with task requirement; neither did they realize what routine tasks were and when they were due. Routine tasks were not regularly scheduled or were rarely discussed (Table 4-62). For example, "writing minutes" was one routine task that a team was required to complete in every meeting. When JR prepared the meeting agenda in the project planning meeting, he mistakenly listed "Determine how is in charge of writing minutes" as one of the task organizational tasks. Neither did JR realize the immediate due day of the team's progress report, as shown in Table 4-61 below.

Table 4-61

An Example of JR's Unawareness of Tasks _ Alpha Project Planning Meeting

Line No.	Participants	Conversation transcripts
1	JR	I just don't know how detailed we can get if we really don't know. I don't feel I understand what we have to do by when.
2	LS	Well for starters we need to do these progress reports every week, and there's actually 1 due tomorrow, I think so, and I mean I just wanted to outline some of deadlines for our project so we know kind of what we have to do every week.
3	JR	Okay. I didn't know there was a progress report due this week, that's kind of soon.

Table 4-62

Team Alpha's Routine Tasks Completed by Member and by Meeting

Selected SameTime Meeting	GA	JR	AB	LS
Sept. 12 (Lab 1meeting) *No discussion regarding completing the individual survey	Meeting moderator: set up the meeting, saved the meeting, Whiteboard notes, and chats, and closed the meeting "Recorder" specifically for this activity: recorded teams' ranking and rationales	No discussion	No discussion	No discussion
Oct. 05 (selected project planning meeting)	Proofread LS's work breakdown structure and work schedule once LS completed	Meeting moderator: set up the meeting, saved the meeting, Whiteboard, and chats, closed the meeting Also responsible for taking and uploading the meeting minutes to the team dropbox and writing the team's progress report	Would be the meeting moderator for the next meeting and will take care of the meeting minutes for the next meeting as well	Post work schedule including work break-down structure and deadline calendar
Nov. 6 (selected project working meeting)	No discussion	No discussion	No discussion	No discussion

Potential influencing factors.

Data suggested that Alpha students' task management activities and behaviors may be significantly influenced by urgent deadlines. At the project working meeting, Alpha students faced an urgent deadline of PDR presentation which was due the next morning. Students had only a short period time (one night) to complete their presentation slides, making corrections and modifications. The presentation deadline "pushed" Alpha students to stay concentrated and focused on task-related activities.

Different from team Gamma, the role of the meeting agenda seemed minimum in helping Alpha students to stay on track of tasks and control their time use. The team only used a meeting agenda in its project planning meeting. Different from team Gamma, Alpha students did not lay out clearly-described task details in the meeting agenda; neither did they include estimate completion time for every scheduled task. Before the meeting ended, students did not check the completion of scheduled tasks either.

Temporal planning.

In response to research question 1 regarding individual behaviors in temporal planning, data suggested that Alpha students had few temporal planning activities. Such pattern was consistently observed in the following evidence across the three meetings.

First, team Alpha students did not complete scheduled tasks within the meeting time as described above.

Second, different from team Gamma, Alpha students' progress on the design project may considerably fall behind (see the two examples observed in the project working meeting in Table 59). As the first example shown in Table 4-63 below, the team was struggling on their design needs at the final evaluation stage of the team's preliminary design in the selected project working meeting. Students were not sure whether the objective of their design project was to design a whole system or the plate. By the time of the selected project working meeting, every team should be at the final evaluation and production stages for their preliminary design. However, team Alpha still needed to review the task guide description to understand the design needs and objectives, which should be discussed and completed at the "define the problem" stage when the design project started based on the course instruction described above.

During the project working meeting (see the second example in Table 4-63), GA asked AF about the thermal analysis results. AF responded to GA that there should be a nomex like sheet to be attached by using some glue and the team had not worked on this part yet. According to the course instruction, this design issue should be completed during the implementation stage of a team's preliminary design. Comparatively, team Gamma worked on this topic in their meeting on Oct. 27th and Gamma students had conducted a certain amount of research and found a potential solution.

Table 4-63

Examples of Team Alpha's Work Progress

Line No.	**Participants**	**Conversation transcripts**	**Comm. Channels**
		Example 1	
1	JR	Ok, do you guys feel we need to change this at all? I feel it might be ok. Same thing, anything need to be edited?	
2	GA	Thermal structural protection system, it's just thermal protection system,	
3	GA	right? or should we, does that sound right to everybody?	
4	GA	I think it is something like thermal protection system and pressure vessel. I don't know, something like that.	
5	JR	And what?	
6	GA	Pressure vessel.	
7	JR	Okay.	
8	JR	Well I guess I put Pressure vessel.	
9	JR	*I think we properly design the whole system, I feel kinda odd, I don't know.*	
10	LS	Actully I think we are designing… the panel part. And we are doing this specific panel. And once we are together, then we are doing this whole card.	
11	LS	Maybe we should put that as primary	
12	JR	I'm sorry, I didn't hear that	

Line No.	Participants	Conversation transcripts	Comm. Channels
13	LS	We're just in charge of designing the panel for CEV as opposed to the entire system. And I guess	
14	GA	I think thermo-structural protection system sounds incorrect, you?	in chat
15	GA	btw, JR, want to come over or voice versa so we can practice the slide show real time?	in chat
16	GA	later tonight	in chat
17	GA	I slept from 6 to 9 so I'm finally awake	in chat
18	JR	I don't know. I'm not… any words. I'm not… Anybody?	
19	AF	Yeah	
20	JR	I hear you but I don't know how to put in words.	
21	GA	what's going on now?	in chat
22	AF	Uhm, *does it say anything in the actual guide descriptions?*	
23	AF	Em, it says… 90 degree thermo structure concept	
24	JR	I'm sorry AF what?	
25	AF	In the design project description, it called the thermo structure concept	
26	AF	thermo-structural concept	in chat
27	LS	"to design a titanium TPS panel for the CEV, which will be compared to other materials and panel design"	in chat
		Example 2	
28	GA	Let's just say, send me an email with anything you think I might need to know, like... you just iterated that uhm, the thicknesses until you got three and a half millimeters, uhm, data was, did you do it at two and a half and see that it was too small or did you just quit at 3 and a half?	
29	AF	I just quit at three and a half honestly.	
30	GA	So we actually go even thinner?	
31	AF	Yeh, I mean looks like we probably could. The only thing that you might, I don't know if you want to mention this, it might be something just to like say, that on the installation is attached using like a nomex like sheet that like has to do with the strain. I don't know, that maybe not really important.	
32	GA	I would mention that we haven't worked out the details yet of how we would attach it, but we realize we would use some sort of compound… probably the best way to.	
33	AF	Yeh I think the thermal protection system, that *some document is pretty explicit about how to attach it, there's like a blanket and then glue, something like that.*	
34	GA	If they ask us questions about it, we are going to say "Hey that's later, right now we are just learning how to do this." I think we can self explain ourselves.	
35	AF	Yeh, alright that's fine with me. I think that maybe just be honest with them, I mean, whatever.	

Technology use.

In response to research question 1 regarding individual behaviors in technology use, Alpha students regularly used video, audio, chat, whiteboard, and shared applications in the selected three meetings. Alpha students used Whiteboard to display meeting agenda and team documents and the pen tool in Whiteboard to note discussion results. Shared application was utilized by students to share and collaborate on team documents simultaneously. Chats were frequently used to complement the meeting conversations, especially when the issues, such as voice cut-offs or audio break-downs, arose.

The frequency of such issues seemed to increase across the three meetings. In Lab 1 meeting, voice cut-offs barely interrupted the team discussion. However, when came to the project planning and working meetings, voice cut-offs were more frequently observed and students had to constantly ask the speaker to repeat what he was saying. There were two reasons which may explain team Alpha's frequent technology issues: (1) the team did not always do technology normalization when students entered the meeting and (2) the team used the shared application in both the project planning and working meetings. Use of screen sharing, which may facilitate the team's communication in virtual meetings, nevertheless consumed a great amount of capacity from limited internet bandwidth and caused frequent voice cut-outs and audio break-downs.

When a student's voice got cut off, he was informed by other students. However, students did not seem to care about why their voice was cut out or to do a technology check. Occasionally, students offered ideas to help with the technology issue. Or students helped each other when their partners did not know how to use certain tools in Sametime.

As described above, Alpha students frequently used chats to complement verbal conversations. Chat was helpful to complement spoken conversations or be as an independent communication channel because its advantages in: (1) delivering information without interrupting the spoken conversations and (2) offering students opportunities to present ideas or information in writing when they were experiencing audio break-downs or voice cut-outs. In response to research question 1-1 regarding individual behavior changes in technology use, Alpha students' use of chat increased consistently across the three selected meetings. Using chat seemed becoming a habitual behavior when the team's spoken conversation cannot be delivered smoothly. Students used chats to ask questions, send responses, offer explanations, and had task-unrelated side talks. Table 4-64 below showed the frequency of chat use in the three selected meetings.

Table 4-64

Use of Chat _ Team Alpha

	Frequency	**Frequency%**	**Word Counts**	**Word Counts%**
Lab 1	7	2.2%	28	0.5%
Project Planning	60	21.8%	331	8.0%
Project Working	132	27.0%	827	13.1%

As a summary, data suggested that Alpha students may have lacked knowledge in team planning and management in general. Neither may they have had sufficient skills to realize planning activities in actual problem-solving practices. In response to research question 1, Alpha student individual behaviors were evidenced as: (1) chose the discussion items randomly: no task management or temporal planning strategies were observed, (2) were not clearly aware of task requirements and observed to frequently revisit task description, (3) no strategies were discussed and no procedures used to monitor individual work progress and evaluate the team's design project status, (4) did not complete scheduled tasks within the meeting period and leaving unfinished work until after the meeting seemed to become an habitual behavior for Alpha students, (5) some individual members had poor time management and affected team negatively. They either were not able to complete the work in a timely manner or had other academic obligations conflicting with their responsibilities in this course, and (5) no regular technology normalization was conducted when entering the meeting and did not provide timely solution to technology issues. Alpha students were also observed to provide limited individual working days for team meetings and they did not have clearly-written meeting agendas as those of team Gamma. Neither did the team follow its meeting agenda to organize meeting sequence. In response to research question 1-2 regarding how individual behaviors may affect team performance, Alpha students' behaviors limited individual students' and the team's success in having a fruitful discussion, establishing a strong time awareness, and prevented the team from developing high level behavioral interdependence in planning behaviors.

In response to research question 2 regarding team behaviors, team Alpha showed unstructured problem-solving sequence, including frequent changes of discussion items, repetitive visits of the same topic, extended meeting duration, and decreased productivity.

Comparing the two teams, Alpha students were observed to have different behaviors from Gamma students in planning.

In task management, behavior differences between the two teams were observed as: (1) different from team Gamma who had an organized discussion structure and the team was often observed to discuss working strategies together, Alpha team was rarely observed to have team discussion regarding task management or working strategies. Alpha team was observed to have unstructured discussion sequences and their choice of discussion items was random, (2) different from team Gamma's frequent discussion of task requirements, Alpha students seemed not being familiar with the task requirements including both routine tasks and the design project, (3) different from team Gamma who followed its meeting agendas, team Alpha did not have a regular meeting agenda posted and the role of the meeting agenda seemed minimal in helping Alpha students stay on track of tasks and manage their time use. Also different from team Gamma, Alpha students did not lay out clearly-described task details in the meeting agenda;

neither did they include an estimate of completion time for every scheduled task, and (4) different from team Gamma, Alpha students' progress on the design project appeared to be considerably falling behind.

In temporal planning, behavior differences between the two teams were observed as: (1) different from Gamma team who completed tasks within the meeting period, team Alpha was not observed to complete scheduled tasks in a timely manner, (2) different from Gamma team who worked out time-efficient strategies, team Alpha had extended meeting duration due to issues such as technology break-downs, missed information, repetitive questions, and (3) different from team Gamma who was observed to have strong time awareness and plan their design steps strategically, Alpha's students' task-related behaviors and its design progress seemed largely influenced by urgent deadlines.

And in technology use, behavior differences between the two teams were observed as: (1) different from team Gamma regularly conducted technology normalization, Alpha team rarely did technology normalization when entering the meeting, and (2) different from team Gamma who stuck to basic communication tools, team Alpha seemed more willing to experience new technology. However, Alpha students seemed to not realize that use of shared applications consumed a large amount of bandwidth capacity, which caused the technology break-down and voice cut-outs and led to extended meeting duration.

Decision-making.

Team Alpha's decision-making behaviors were reported in two areas: information communication and decision-making. The information communication results are reported in 3 aspects: (1) what information being communicated, (2) how information was communicated, and

(3) how Alpha students' information communication behaviors may influence members' interactions, team behaviors, team collaboration, and performance.

Information communication.

Information being communicated.

In response to research question 1 regarding individual behaviors in information sharing, data suggested that Alpha students used informative conversations to deliver information including technology issues, completed actions, current behaviors or actions, future actions, personal perspectives and knowledge, and confusions. Table 4-65 below listed some of team Alpha's informative conversations.

Table 4-65

Examples of Informative Conversations _ Alpha Lab 1

No.	**Participants**	**Conversations**	**Informative Comm. Functions**
Example 1	GA	Testing 1, 2, 3. Okay good I got video.	Informative: informed current actions
Example 2	JR	Big, you are a little off screen.	Informative: informed technology issue
Example 3	GA	It's even worse on the moon.	Informative: sharing knowledge
Example 4	AB	so I just put the milk cause I would drink.	Informative: informed personal opinion
Example 5	JR	I'm free from 9 to 1, like 9:30 to 1, wasn't like there a time that we can meet	Informative: informed personal schedule
Example 6	JR	I just don't know how detailed we can get if we really don't know. I don't feel I understand what we have to do by when.	Informative: informed personal understanding confusion
Example 7	JR	Okay. I didn't know there was a progress report due this week, that's kind of soon.	Informative: informed unawareness of a task
Example 8	LS	it's on the 9-12 lecture by Prof. Z	Informative: informed the information source within the course
Example 9	JR	Yeah, the 17th, we need the teams present their plan from here to PDR.	Informative: informed due dates
Example 10	GA	By the way, I don't even know when we're going to start working on this	Informative: informed DST (FEA) training status

No.	Participants	Conversations	Informative Comm. Functions
		project because, at least AB and I, I mean, we barely even know how to get a plate made in ANSENSE (cut off) so how we're going to start analyzing stuff and data and you don't have enough stuff with AS to start to create a plate so I don't know how close to getting the design date and start crunching.	
Example 11	GA	Well, we've got another week.	Informative: informed project progress
Example 12	LS	I was going to post a little bit of the work schedule and deadline calendar on Monday	Informative: informed future actions
Example 13	JR	I saved the minutes in the teamwork space	Informative: informed completed actions
Example 14	JR	I hear you but I don't know how to put in words	Informative: informed difficulties
Example 15	JR	I thought we were just putting on the next slide.	Informative: informed misunderstanding

How students communicated information.

Due to technology issues, frequent voice cut-outs were observed. In such situations, Alpha students adopted several strategies to ensure the fluency of their discussion. In response to RQ 1 regarding individual behaviors in information sharing, students had to *ask* speakers to repeat their words in order to fully capture shared ideas, questions, information, and suggestions. As noted above, c*hat* was also often used to supplement students' verbal conversations.

Alpha students were active in expressing their ideas or opinions. However, students were seldom observed to check each other's understanding; neither did they provide verbal acknowledgement or feedback to ideas or information being shared. Occasionally, students were observed to comment on ideas or summarize shared information to confirm understanding. There are a few occasions that students asked questions when they did not understand shared information. Explanations were provided in details when students asked questions or required further explanation. However, timely explanation was not provided on a regular basis due to several meeting pauses described above, which led to repetition of questions.

Outcomes of information communication.

In response to research question 1-2 regarding how individual behaviors may affect team performance, issues including meeting pauses, frequent voice cut-outs, untimely responses or explanations, and ignored questions or information, resulted in team Alpha students' behaviors such as repetitive questions, waiting for technology issues to resolve, waiting for a meeting to resume, misunderstanding, or reaching agreement without sound reasoning or a thorough discussion. These behaviors further lead to extended meeting duration and decreased meeting productivity.

Reaching decisions.

In response to research question 1 regarding individual behaviors in decision-making, Alpha students were observed to offer different perspectives, complement each other's knowledge, and help build new knowing. Students relied on their partners to correct misunderstanding (e.g., AB corrected GA's understanding of the Lab 1 task requirement in Table 4-66) or extend understanding (e.g., members' collective efforts in establishing mutual and correct understanding of the ranking criteria among them in Table 4-67).

Table 4-66

Correction of Understanding _ Alpha Lab 1

Line No.	Participants	Conversation transcripts	Comm. Functions	Decisions
1	GA	Alright so now we have to compare and discuss the single team rankings. .	Organizational	
2	GA	Okay so now we can only pick the top 5, then we're done. Alright, uhm	Organizational	
3	AB	Don't we have to complete ranking and then rationales for the top 5?	Interrogative	
4	GA	Yeh, some rankings then rationales.	Responsive	

In Table 4-67, Alpha members had different ranking opinions because they had different understanding of the task criteria. Therefore, LS suggested the team review the document again together. When the team reviewed the specific requirements, all members agreed that keeping survival and staying close to the obiter ship were the two criteria on which their team ranking should be based. In this example, establishment of the ranking criteria relied on members' collective effort, especially JR and GA, in sharing ideas, presenting perspectives and reasoning, checking documents, and correcting misunderstandings.

Table 4-67

Extending Understanding _ Alpha Lab 1

Line No.	Participants	Conversation transcripts	Comm. Functions	Decisions / Agreement
137	LS	So I think the most important things is just what is going to allow us to survive for more a longer amount of time,	Suggestive	
138	LS	is that, I mean ,we're just going to go with that ranking?	Interrogative	
139	JR	Yeh, that's how I started mine.	Responsive	
140	JR	I just have to make individual survival impossible. Uh, cause stuff that makes, it's stuff we can't live without. Uhm, like water, oxygen and food, I put pretty much at the top.	Reasoning	
141	JR	I don't think it really matters the order of the first couple because if we don't have any of them, you are not going to make it 250 miles.	Suggestive	
142	AB	But then again I mean you don't need to be doing like you don't need to go 250 miles, maybe you can just try	Argumentative	

Line No.	Participants	Conversation transcripts	Comm. Functions	Decisions / Agreement
		to go 20 miles and then in that time make contact with the radio and uh, you know, use your signal flares and get attention.		
143	AB	But I think I agree with the former plan of going with immediate survival necessities.	Responsive	AB agreed with JR and LS that to satisfy immediate survival necessities is the first rationale for ranking
After PAUSING about 15 seconds				
144	AB	So water number 2?	Interrogative	
145	GA	Uhm, I think this could be splitting hairs here cause it seems like a priority along with everybody except Otto,	Responsive	
146	GA	but the stellar map was up in the top 5.	Suggestive	
147	GA	I just got it as a second priority because if you don't have a map and you have no idea where you are on the moon, you are never going to get anywhere close to the rendezvous site. So that's why I think stellar map is number…	Reasoning	
148	JR	Yeh that at least you stay alive, I mean like if you are trapped in the driveway, they tell you to stay like, make sure you are secure before you start like looking around for people.	Argumentative	
149	GA	I believe one of the… (inaudible)		
150	LS	Do you want us to go back to the problem outline, so we can see if there is anything I missed?	Suggestive	
The team changed the WB slides to P. 1 problem statement and outlines. Someone highlighted the requirements in the document "…as staying alive as long as to get a close as possible to the orbiter ship"				
151	JR	I think it's pretty important.	Responsive	
152	LS	Yeh we are definitely on our own so.	Agrees	
153	AB	So I guess our philosophy is to stay alive as long as possible to get a close as possible to the orbiter ship.	Confirmative	
154	GA	I agree,	Agrees	GA agreed with AB and JR's understanding of the guideline that staying survival and being close to the obiter ship are priority rationale for team ranking

However, not every decision was based on sound reasoning and objectivity. In response to research question 1 regarding individual behaviors, data suggested that Alpha students sometimes involved personal feelings in their reasoning and decision-making processes. In the first example shown in Table 4-68 below, AB suggested that the team could start ranking the top 5 items before continuing with rest of the items (Line No. 165). Then in line No. 172, he suggested including the milk or the food in the top 5 list and reasoned that he would include milk simply because he would drink. The reasoning he provided was not based on an analysis of the moon environment, features of the milk, or the two ranking criteria indicated in the task description (i.e., the survivability need and getting closed to the obiter ship). AB's ranking was merely based on his personal preference or interest. In the second example in Table 4-83, GA asked whether water was included in the team's top 5 list. AB responded that he also agreed to have water in the top 5 list. JR disagreed because he thought the team may only need to stay a day before they got rescued. As response to JR's disagreement, AB suggested to include at least water if food would not be included because the team may need to stay more than a day. After listening to AB's reasoning, JR did not argue back; instead, he responded by saying "okay alright, we can put water on there if you really want it" (line No. 302), which sounded involving some personal feeling. AB then responded with some personal emotion involved "Don't worry, there won't be any hard feelings."

Table 4-68

Involvement of Personal Feeling in Reasoning _ Alpha Lab 1

Line No.	Participants	Conversation transcripts	Comm. Functions
		Example 1	
165	AB	so maybe we could just go around and try to look at the top 5 with each person or try to get the top 5 ready first before dealing with the other ones.	Suggestive
166	LS	AB I can hardly hear you when you are speaking	Informative
167	LS	if you can turn up your mic or, I think that would help a lot.	Suggestive
168	AB	Alright I'll make it after.	Responsive
169	Meeting PAUSED for about 15 seconds		
170	GA	Alright so that's…	
Someone was drawing a right arrow on the left side of "Food concentrate" on the team ranking table			
171	AB	I seeing the milk or the food, or you could have one of those, you need one of those in the top 5 but you could,	Suggestive
172	AB	so I just put the milk cause I would drink.	Informative
173	JR	Yeh that'd be great. Definitely don't need those but uh, actually we should be in the top 5 or we shouldn't I don't really feel strongly about it one way or another.	Responsive
		Example 2	
296	GA	So are we doing... it? Wait do we have water? Yeh I guess do you want to make water number 5? Is that in agreement?	Interrogative
297	AB	Yeh I want water to be in the top 5.	Responsive
298		**Adil and Justin bumped into each other**	
299	GA	Justin you want to say something?	Interrogative
300	JR	I wasn't going to put up there for all, if we're only staying the day.	Responsive
301	AB	...I don't know if you would at least have water if we're going go with the food, we should at least keep the water so if anything goes wrong we have at least one more day to survive to try. I don't know if we're going to do a crazy plan or not but, I'm assuming that our space suit has something that can maybe uh, or no if they don't have oxygen, uhm,	Suggestive
302	JR	Okay alright, we can put water on there if you really want it.	Responsive
303	AB	Don't worry, there won't be any hard feelings.	Affective

In the team's selected project working meeting, Alpha students were observed to use more rationales and reasoning compared to their' performance in Lab 1 meeting. In response to RQ 1 regarding individual behaviors in decision-making, Alpha students were observed to pay more attention to task-relevant information and tended to obtain a thorough understanding of design issues in the project working meeting. The example in Table 4-69 below showed how the team Alpha reached an agreement after AB helped the team understand his work of the buckling analysis graphic in the selected project working meeting. Also after the team had mutual understanding of AB's work in buckling analysis, the team started to figure out a best way to present AB's buckling analysis results. Initially, JR, GA, and LS were very confused about the shape of the buckling graphic so they decided to get rid of the buckling graphic. AB then jumped in to explain about the shape. Since GA and AB were at the same DST class and learnt the ANSENSE together, so GA argued that the increased thickness would not cause buckling. AB then provided more detailed information about the buckling analysis and apologized that he did not give the deformed shape picture to the team. The team then had a clear understanding of AB's work and continued to discuss how to better explain the buckling shape in the presentation.

Table 4-69

Reaching Decisions/Agreement through Cleaning Misunderstanding _ Alpha Project Working

Line No.	**Participants**	**Conversation transcripts**	**Channel**	**Comm. Functions**	**Decisions / Agreement**
1	AB	Wait I don't understand why you are taking it out.		Responsive to Q	
2	AB	Uhm, from the ANSENSE model what is happening is that there are I think both global and local buckling is happening but at different times.		Explanative	
3	GA	Buck in structures class we've never seeing increased thickness causing buckling	in chat	Argumentative	
4	JR	I thought we were just putting on the next slide.		Informative	
5	JR	Isn't that what this means?		Interrogative	
6	GA	Yeh that is what it means.		Responsive to Q	
7	GA	Uhm, I'm just going to... summary page and then having a data page.		Informative	
8	GA	Uhm, all the things that you and I are kind of uneasy about that data because we don't know exactly why it is buckling at higher thicknesses cause we never learned anything in that in structures class.		Explanative	
9	AB	No, what is going on is that and it is stupid of me, I forgot to say is like the middle plots, like the middle thicknesses from like five to twenty, I forgot to save the deformed shape, but when it is really thin, there is global buckling meaning that the whole plate		Explanative	

Line No.	Participants	Conversation transcripts	Channel	Comm. Functions	Decisions / Agreement
		is bending. Uhm, is like 30 millimeter for example, 30 and 40, what's happening is only a couple of the stiffeners have buckled whereas while the plate itself, the titanium sheet is still like has maintained its shape.			
10	GA	Oh okay, alright now I follow you.		Informative	
11	GA	Is there any way you can type that up and put that in the annotation so I will know to mention that when I, when the data comes up with the next slide just so I can mention that? And also you can just put graphic just to uhm, if you have any pictures of the stiffen sheet, if you can give that to JR, just put next to those three bullets just uhm, so that you know….		Suggestive	
12	AB	The one that shows…?		Interrogative	
13	GA	It doesn't matter, just one in… just so people won't even need to read the bullets, they will just see a…. and a sheet of… buckling in the and they will say, "Oh okay they are talking about buckling."		Responsive to Q	
14	AB	Should I give those global and local buckling or at least what I think is going on?		Interrogative	
15	LS	Uhm, you could also…		Responsive to Q	
Everyone talked at the same time					
16	GA	You go on, LS….		Organizational	
17	LS	I was just saying you could split the graph up so that like it said, like just draw a line and say "One buckling is this way and one buckling is that way." Or you could kind of extend the curve like with the dotted line or something.		Suggestive	
18	GA	I could even just trace it out with my finger while I'm presenting it and just say, "Hey this particular kind of… the entire stiffen sheet was buckling up until this point meanwhile, only the stiffeners were buckling."		Suggestive	
19	GA	I just don't want to use local and global yet just because… I don't know, the last thing I want to do is say "Well its buckling globally here and locally here," and then have Davidson shoot me down and rip me to shreds in case I am wrong. But I would rather say it this way first.		Explanative	

Line No.	Participants	Conversation transcripts	Channel	Comm. Functions	Decisions / Agreement
20	AB	That's fine then.		Agrees to S	AB agreed on GA's suggestions of verbalizing the two buckling situations in the PDR presentation

As a summary, data suggested that a moderate level of behavioral interdependence emerged from Alpha students' decision-making processes. In response to research question 2 regarding team behaviors, Alpha students were observed to have several promotive interaction which can contribute to their mutual understanding of shared information. Members' promotive interaction include individual student behaviors such as actively expressing ideas, sharing knowledge contributable to building new knowledge, and providing explanation to help clarify misunderstanding. However, establishment of mutual understanding and decision-making were challenged by student behaviors or situations such as (1) missed information and unsolved questions, caused by reasons such as simultaneously using two communication channels, sometimes prevented students from obtaining complete knowledge and forming solid understanding of shared information, (2) students were seldom observed to check each other's understanding; neither did they provide feedback or acknowledgement to confirm understanding, which may result in unrevealed confusion and misunderstanding, (3) timely explanation were not provided on a regular basis, and (4) decisions were sometimes not based on sound reasoning and personal feeling may be involved in. These behaviors were constantly observed across the three selected meetings. In response to research question 2-3 regarding how team behaviors may affect team performance, such behaviors could frustrate information sharing and establishment of mutual understanding, which further discourage students' motivation in working on their design project.

Comparing the two teams, team Gamma and Alpha were observed to share some similarities and differences in their behaviors in information-sharing and decision-making: (1) similar to Gamma students who used several strategies to ensure mutual understanding, Alpha students also used strategies such as asking and explaining to ensure the fluency of team discussion, (2) similar to team Gamma, Alpha students were observed actively expressing ideas and sharing information, offering different perspectives, complementing each other's knowledge, and helping build new knowing. Students relied on their partners to complete their understanding and correct their misunderstanding, (3) different from team Gamma's effective information communication, mutual understanding may not be regularly guaranteed among Alpha students because timely explanation was not provided on a regular basis, and (4) different from team Gamma who made vigilant decisions based on rationales, reasoning, and careful evaluation of information, Alpha members sometimes involved personal feelings in their decision-making process, especially at the initial stage of their collaboration.

Section 2 reported individual and team behaviors of team Alpha, documented behavior changes across the three selected meeting, and described how individual and team behaviors may be associated with performance. Table 4-70 summarized team Alpha's individual and team behavior data in response to the two research questions.

Table 4-70

Team Alpha Behavior Summary in Response to Research Questions

Evaluation Aspects	**RQ1-1 What individual behaviors are observed and how do these behaviors change over time?** **RQ1-2 How do individual behaviors affect team performance?**	**RQ2-1 What team behavior patterns are observed?** **RQ2-2 How do team behavior patterns and students' interactions change over time?**	**RQ2-3 How do student interactions and team behaviors affect team performance?**
Communication	Alpha students consistently showed behaviors: 1. Individual students' behaviors which led to frequent meeting pauses: (1) simply paused speaking simultaneously, (2) left seats to grab water or for other personal matters, and (3) no regular technology-normalization and left technology issues unsolved 2. Using chat to complement their verbal conversation during technology break-downs. Use of chats extended conversations channels but sometimes distracted students' focus and led to ignored messages or not-responded questions 3. Introducing a new topic without finishing discussion of the previous item resulted in ignored information and questions 4. Students spent a certain amount of meeting time on joking or goofing around. Students sometimes introduced jokes and games into meeting discussions and was not able to quickly draw their attention back to tasks 5. Students did not keep individual meeting environment quiet and background noises	Team Alpha was consistently observed: 1. Meeting often paused due to reasons including: (1) frequent technology breakdowns and voice cut-outs, (2) students' simultaneous pause of speaking, and (3) the team waited for students to come back from personal matters 2. The team had a moderate level of response rate to questions and suggestions: several questions and suggestions were ignored and not responded 3. The team often had task-unrelated affective conversations, which drew the team's attention away from the tasks 4. Background noises from students' sitting environments were often heard during meeting discussions	Data suggested that situations, including frequent meeting pauses, ignored questions and suggestions, and interrupted communication flow, occurred frequently in team behaviors. These situations led to delayed meeting progress, extended meeting duration, decreased meeting productivity and further led to frustration and discouraged working morale

Evaluation Aspects	RQ1-1 What individual behaviors are observed and how do these behaviors change over time? RQ1-2 How do individual behaviors affect team performance?	RQ2-1 What team behavior patterns are observed? RQ2-2 How do team behavior patterns and students' interactions change over time?	RQ2-3 How do student interactions and team behaviors affect team performance?
	from their sitting environments were often heard during the meeting	5. The team's participation rate does not consistently stay even among students	
Planning	Individual Alpha students <u>consistently</u> showed behaviors: *Task management*: 1. Planning actions or discussion of problem-solving strategies was rarely observed. Alpha students were frequently observed to randomly start a new topic without finishing previously-discussed topic, which resulted in: a. Ignored information and not-responded questions b. Repetitive discussion of a same topic due to unorganized discussion sequence 2. Students were not well aware of required tasks, which resulted in: a. Revisit of task description and extended meeting duration b. Routine tasks were not regularly scheduled or discussed 3. Did not have a clearly-written meeting agenda 4. No actions to examine individual work progresses or evaluating team design project status	Team Alpha was <u>consistently</u> observed: 1. The discussion was unstructured and choice of discussion items was random 2. Unfamiliar with task requirements 3. Meeting agenda played a minimum role in helping Alpha students stay on track of tasks: deadline seemed promoting more task-related activities and "pushing" students to stay focused 4. Completion of scheduled tasks within meeting periods was barely observed 5. Different from team Gamma, Alpha students may fall behind on their design progress 6. Frequent technology issues frustrated communication and delayed meeting progresses	Data suggested that: 1. Team Alpha students' behaviors in team planning, management, and technology use may prevent the team from forming an organized problem-solving sequence, which can further contribute to the team's frequent changes of discussion items, repetitive visits of a same topic, extended meeting duration, and decreased productivity. 2. Alpha students' behaviors can further limited each other's and the team's success in having a fruitful discussion,

Evaluation Aspects	RQ1-1 What individual behaviors are observed and how do these behaviors change over time? RQ1-2 How do individual behaviors affect team performance?	RQ2-1 What team behavior patterns are observed? RQ2-2 How do team behavior patterns and students' interactions change over time?	RQ2-3 How do student interactions and team behaviors affect team performance?
	Temporal planning: 1. Students did not complete scheduled tasks within the meeting period 2. Offered limited availability during weekdays for team meetings *Technology use*: 1. Students frequently used video, audio, chat, whiteboard, and shared applications for communication purposes 2. Students did not conduct regularly technology normalization when entering a meeting, which might be one reason to cause frequent voice cut-out and technology break-downs and further resulted in paused communication 3. Efforts on providing timely solutions for technology issues were occasionally observed		establishment of a strong time awareness, and formation of high level behavioral interdependence.
Decision-making	Individual Alpha students <u>consistently</u> showed behaviors: 1. Use of two communication channels simultaneously sometimes resulted in missed information 2. Students rarely checked each other's understanding when sharing information; neither did they provide feedback or acknowledgement to confirm understanding	Team Alpha was <u>consistently</u> observed: 1. Confusion and misunderstanding were sometimes observed: explanation was not regularly provided in a timely manner 2. Weak checking and confirming behaviors on understanding shared information	Data suggested that Alpha students' behaviors during their decision-making processes may be associated with the team's frustrated communication and can further discourage

Evaluation Aspects	RQ1-1 What individual behaviors are observed and how do these behaviors change over time? RQ1-2 How do individual behaviors affect team performance?	RQ2-1 What team behavior patterns are observed? RQ2-2 How do team behavior patterns and students' interactions change over time?	RQ2-3 How do student interactions and team behaviors affect team performance?
	3. Explanation was provided at an appropriate level but was not regularly offered in a timely manner due to reasons such as meeting pauses or technology issues 4. Individual students' sharing and explanation of knowledge and varying perspectives complemented each other; which consequently resulted in new knowing, corrected misunderstanding, and facilitated decision-making 5. Decisions were sometimes not based on sound reasoning and objectivity. Personal emotion and feelings may be involved in	3. Explanation was provided at an appropriate level and such explicit explanation contributed to reduced misunderstanding, creation of new knowing, and facilitated decision-making 4. Team decisions may sometimes be affected by personal feelings	students' working motivation

Section 3: Team Alpha and Gamma Student Behavior Comparison

Comparing the two teams, data suggested that major behavior similarities and differences between the two teams fall in to two themes: *the nature of social communication in collaborative decision-making* and *task management and temporal planning*.

The nature of social communication in collaborative decision-making.

Team Gamma: Case 1 described Gamma students' collective working behaviors and efforts when they were working together on Lab 1 task and the design project. Gamma students' social communication behaviors and teamwork strategies appear to support the formation of behavioral interdependence and enhanced collaboration.

In response to RQ2 regarding team behaviors, Gamma students' social communication was primarily characterized by behaviors of interrogating, responding, suggesting, explaining / elaborating, informing, reasoning, and organizing conversations. They constantly participated in these seven activities across the three meetings. The high response rates to questions (100%) and suggestions (97%) seemed encouraging interdependent relationship among Gamma students.

As described above, team Gamma's communication was coherent and highly collaborative and this trend grew stronger across the three meetings. Data suggested that Gamma students' behaviors were highly interdependent on each other and contributed to individual students' and the team's success, reflecting a high level of mutual understanding and working momentum. Team Gamma students' social communication included behaviors such as ask-and-respond, reasoning, and argumentation, during which they helped each other to understand shared knowledge and information through explanation and elaboration with the use of tools such as drawing graphics for demonstration purposes.

Data suggested that team Gamma students may have become a highly interdependent social entity in which they relied on each other on resources, knowledge, skills, and ideas. The team built up their communication norms, problem-solving strategies, and decision-making together. Gamma students also critically evaluated shared information as well as potential solutions. The team's decisions were built upon students' mutual, explicit understanding of the problems and made through students' sound reasoning and objectivity.

Team Alpha: Case 2 described that the team Alpha collaboration was constantly challenged by its communication issues and the team's unstructured problem-solving sequence. Data suggested that team Alpha students lacked a clear understanding of required tasks and missed some of the shared information due to meeting pauses.

In response to RQ2 regarding team behaviors, Alpha students' social communication was primarily characterized by behaviors of responding, interrogating, informing, suggesting, and affective conversations. When facing urgent time pressure from the PDR presentation deadline in the project working meeting, Alpha students were observed to become more task-focused. Correspondingly, their participation in explanative / elaborative and organizational conversations increased dramatically in the meeting.

Similar to Gamma students, Alpha students were able to maintain a basic communication flow. However, team Alpha's discussion sequence was not coherently connected and students' communication was often broken down due to technology issues or meeting pauses. This trend continued across the three meetings. Team Alpha students also frequently introduced personal emotions or task-unrelated jokes into the team discussion. Different from team Gamma students, team Alpha students tended to stay with the jokes for a longer period of time before they turned their focus back to tasks. The team decisions were not consistently based on sound reasoning or objectivity; personal emotion or feelings were involved. Students seldom checked each other's understanding of shared information, which challenged the team to effectively build mutual understanding among members.

To conclude, Table 4-71 listed behavior similarities and differences between team Alpha and Gamma in communication and decision-making.

Table 4-71

Behavior Differences between Team Alpha and Gamma _Communication & Decision-making

	Team Alpha	**Team Gamma**
Overall		
Interdependence score	76.3%	93.7%
Communication		
Major communicative function activities	Interrogating, responding, informing, suggesting, and affective conversations	Interrogating, responding, suggesting, explaining / elaborating, informing, reasoning, and organizing
Response rates	Response-to-questions rate: 89.4% Response-to-suggestions rate: 82.1%	Response-to-questions rate: 100% Response-to-suggestions rate: 97%
Collaboration flow: turn-taking	Interruptive; broken	Smooth and tightly connected
Meeting participation	Students' participation stayed mutual and even in the first two selected meetings; in the selected project working meeting, the two University A student presenters participated most among all members	Students' participation stayed mutual and became even among GL, BK, and BZ except for MW
Participation in affective conversations	One of the major activities team Alpha participated in; a large portion of team Alpha's affective conversations were task-unrelated; affective conversations distracted students away from the tasks	Team Gamma had minor participation in affective conversations; all affective conversations were task-related; students can quickly draw attention back to the tasks from affective conversations

	Team Alpha	**Team Gamma**
Sitting environments	Noises from students' sitting environments can be clearly heard during the meeting discussion	Quiet and little distraction from the environments
Decision-making		
Information being shared	Information: technology issues, personal opinions, perspectives, and knowledge, schedules, task-related confusions, knowledge sources in the course, and completed, current, and future actions	Information and its related information: technology information, personal opinions, perspectives, and knowledge, schedules, personal findings, task-related confusion or issues, knowlegde sources in or out of the course, completed, current, and future actions, reporting individual work, research findings, analysis results, and special situations
Information communication	Students occasionally checked each other's understanding of shared information or ideas; either would they provide verbal acknowledgement or feedback to shared ideas or information; Took shared information as it was and rarely evaluated them	Used several strategies to ensure mutual understanding from both speakers and listeners Carefully evaluated shared information
Decisions made	Not always based on sound reasoning and objectivity; personal feeling involved	Decisions were made based on students' clear and mutual understanding of the problems and information being shared. Decisions were built upon sound reasoning and objectivity

Task management and temporal planning.

Data suggested that organized team problem-solving sequence and formation of a good temporal norm are likely to contribute to the formation of a high level of behavioral interdependence and a team's success. The two teams are observed to display strong behavioral differences in task management and temporal planning in collaboration.

Team Gamma: In response to research question 2 regarding team behaviors, team Gamma students had an organized discussion and problem-solving sequence and this pattern stayed consistently across the three selected meetings. Students used different strategies to help organize their meeting activities. They started a new task after finishing a previous one. They learned carefully about task requirements, followed meeting agendas, complemented each other to form a thorough understanding of the design problem, and reminded each other with routine tasks. Based on the 6 problem-solving steps suggested by the instructor, the team laid out their seven design steps and planned their design approaches ahead by estimating time and work load for every design step. By following their lab task strategies and design project plan, students completed tasks in a timely manner. Members were well aware of the team's design progress and were able to make timely adjustment to the design plan when necessary. Team Gamma students were also observed to possess a good temporal sense and data suggested that the team may have formed a temporal norm along with their collaborative work.

Team Alpha: Different from team Gamma, Alpha students' discussion or problem-solving sequence was unstructured and students randomly selected their discussion topics without following their meeting agendas. As described above, urgent deadline seemed an important factor to encourage students' team-like behaviors and promote collaboration. When students were facing an urgent deadline (i.e., the PDR presentation was due on the next morning) in the selected project working meeting, they appeared more task-focused and their conversations were more tightly connected.

To conclude, Table 4-72 listed behavior differences between team Alpha and Gamma as observed in task management and temporal planning.

Table 4-72

Behavior Differences between Team Alpha and Gamma _ Planning

	Team Alpha	**Team Gamma**
Overall		
Interdependence score	76.3%	93.7%
Planning and Organization		
Organizational conversations	Average participation ratio: 3.5% Average time spent ratio: 2.8%	Average participation ratio: 7.2% Average time spent ratio: 5.3%
Meeting agenda	Meeting agenda had a minor role in organizing team Alpha's tasks: the team rarely followed the agenda; barely completed the tasks scheduled in the agenda; emergency project working meeting was arranged to deal with the PDR presentation deadline Did not include clearly-written meeting goals, scheduled task time, and outcomes	All required or scheduled tasks were completed within the meeting Contained clearly-written task goals, outcomes, scheduled time, and completion time
Discussion/Problem-solving sequence	Unorganized; topics were randomly selected	Organized
Routine tasks	Team Alpha students did not understand what routine tasks were and when they were due; team Alpha seldom discussed about routine tasks in the selected meetings	Team Gamma students understood what routine tasks were and the due dates of each routine task; the team scheduled routine tasks in every selected meeting, delegated or volunteered for routine tasks, and checked the completion of every routine task in the meeting
Temporal planning	Only used one meeting agenda and did not follow the agenda to complete all the scheduled tasks	Used task requirements or meeting agenda in every selected meeting and completed all the scheduled tasks

	Team Alpha	Team Gamma
	Not aware of each member's work (e.g., LS said I don't get your question; JR and GA did not understand AB's buckling analysis work) Barely finished scheduled meeting tasks No planned design steps observed	Monitored the team's progress and individual students' progress along with the seven design steps planned by the team Well-understood each other's work Completed all scheduled or required tasks by following the task requirements or meeting agendas The team carefully planned seven design steps, which included: identify the problem, define the problem, brainstorm, evaluate potential solutions, implement solutions, evaluate the designs, and final product
Progress and performance	Did not understand what routine tasks were and when they were due Not familiar with the design needs and constantly revisited the design need in task requirements at the team's PDR working meeting Had not done any research about nomex and adhesive for their preliminary design	Were well aware of routine tasks, when they were due, and took actions to complete them Laid out seven design steps and decided deadlines for completing each step; defined the design need at the "define the problem" stage when the project started Had done certain amounts of research about the adhesive at the implementation design stage. The team found the potential adhesive for their preliminary design needs.
Technology issues	Frequent voice cut-outs and audio break-downs; frequent technology issues caused communication break-downs and interrupted the meeting progress.	Barely had technological issues

	Team Alpha	Team Gamma
Technology use and check	Whiteboard, chat (frequent), video, audio, and shared applications Barely did technology normalization Sometimes helped with technology difficulties or issues; seldom did technology check to fix the voice cut-outs; used chat to supplement the voice when students were experiencing voice cut-outs or audio break-downs Used Whiteboard pen tool for games or used chat for task-unrelated jokes or side talks	Whiteboard, chat (occasionally), video, audio Regularly did technology normalization at the beginning of every selected meeting Helped with technology difficulties or issues and resolved technology issues as a team Used SameTime technology and tools for task-related activities

Summary

This chapter laid out analysis results for each of the selected teams to reveal individual students' behaviors from the beginning to the end of a semester and provided evidence to examine the concept of behavioral interdependence in a team's collaborative problem-solving process. Analysis results were organized in a way so that every analysis aspect (i.e., communication, planning, and decision-making) was addressed with appropriate data. The two selected teams were compared and major behavior differences in the formation of behavioral interdependence between the two teams were highlighted. Data suggested that the two teams' behavior differences fall into two themes: (1) the nature of social communication in decision-making and (2) task organization and time management. Team performance data was also compared and synthesized with behavior data so that potential associations between team performance and behaviors were explored. Data suggested that behaviors and performance appeared to be positively associated.

To answer research question 1, data suggested that a high level behavioral interdependence emerged from Gamma student collaboration process compared with a moderate level of behavioral interdependence emerged from team Alpha's collaboration process. Students in the team with a high level of behavioral interdependence were consistently observed to show promotive behaviors such as staying focused on task-related activities and keeping the meeting environment free of distraction. Individual students usually had mutual participation and made efforts to build mutual understanding through behaviors such as openly sharing information, actively sharing ideas, asking for clarification, offering timely and explicit explanation (to address confusion or misunderstanding), providing timely responses, confirming understanding, and acknowledging efforts. These promotive behaviors were observed to grow stronger and to foster positive interaction, effective communication, and increased behavioral interdependence. Data also suggested that students in the team with a high level of behavioral interdependence were observed to be able to well manage their time use, organize their design activities, develop clearly-written task goals, design steps, and outcomes, and complete tasks through activities such as carefully learning about task requirements, following meeting agenda, regularly evaluating project progresses, and pursuing time-efficient strategies. When it comes to decision-making, students in such a team were also observed to carefully evaluate shared information and they usually made decisions after carefully evaluating alternatives with solid reasoning.

By synthesizing performance data with behavior information, it is observed that individual students who performed better in their technical areas tended to show more promotive behaviors in and appeared more participation in and contribution to teamwork; while students who performed poor in their disciplinary, technical areas were observed to contribute little to the team or simply participated in clerical tasks. Students who had poor technical performance also tended to have less effective time management practices and were often observed to miss meetings and have incomplete work.

In addition, the high-performing team can contain low-performing students. In such circumstances, high-performing students made up for the low-performing students and low-performing students were often observed to take the free-ride.

To answer research question 2, data suggested that the team with a high level of behavioral interdependence (i.e., team Gamma) was characterized to have fluent communication flow with smooth turn-taking and high response rates. Such a team was also observed to have better-organized discussions and problem-solving sequences compared with the team with a lower level of behavioral interdependence (i.e., team Alpha). Data suggested the team with a high level of behavioral interdependence regularly pursued effective problem-solving strategies, organizational strategies, and communication tools. Such a team carefully planned project steps, was cautious with time use, and continuously maintained high levels of mutual understanding through behaviors such as asking questions, clarifying confusions, and providing timely explanation. As a result, the team with a high level of behavioral interdependence are more likely to have good decision-making and increased opportunities to succeed in completing tasks with high quality and in a timely manner. Performance data confirmed that the team with high levels of behavioral interdependence had better performance in the design project and received high evaluation from the instructors due to their great efforts. Despite of few minor issues, the team with high levels of behavioral interdependence produced well-written design report with good logic progresses, highly-optimized design, and highly-accurate analysis.

Chapter 5 will continue with discussion of these main findings, research significance, and data implications to future research and practice.

CHAPTER 5 CONCLUSION

This study set out to understand project teams' collaboration process through examining students' collaborative behaviors and investigating the concept of behavioral interdependence by using a descriptive, instrumental case study approach within a distributed, collaborative environment. The study also sought to understand how student behaviors change across different time intervals as well as to identify evidence for the formation and development of behavioral interdependence. The study was set in a context of college engineering students in project teams attempting to solve interdependently-structured engineering problems within a computer-support collaborative learning environment (CSCL). Each project team was composed of students who were distantly locating in two universities and separately received two different types of Disciplinary-Specific knowledge Training (DSTs) in engineering. Members in each project team therefore had to share their DST knowledge and technical skills, coordinate their resources, and work together to solve the problems using the provided communication technologies within a limited course period.

Historically, structural interdependence was viewed as one of the most powerful features to affect members' task-related collaborative behaviors in both laboratory settings and real organizations (Allen, Sargent, & Bradley, 2003; Wageman, Gardner, &Mortensen, 2012). In recent years, researchers have argued that the role of task structural features on predicting members' actual behaviors tends to become ambiguous (Wageman, Gardner, & Mortensen, 2012). The authors argued that rather than accepting the task as it is given and executing it as it is defined, members in project teams, also called self-managing teams (Alper, et al., 1998), often "decide how subtasks are to be allocated and performed" (p. 306). Therefore, it is likely that behavioral interdependence can be "undermined to the point that some teams are team in name only" (p. 307). In other words, students may not show reasonable (amount) of collaborative behaviors as required by tasks. Task features alone do not provide sufficient and appropriate data for us to understand the complex collaboration process; more evidence is needed. At the same time, current theoretical literature on interdependence has not been sufficient to provide a clear description to explain the dynamic phenomenon of behavioral interdependence, especially in the context of project team collaboration within CSCL environments. This study therefore aimed to explore two major research questions:

Research Question 1: *What individual behaviors are observed in project teams as they are working on interdependently-structured tasks?*

Research Question 2: *What patterns of team behaviors are observed in project teams as students are working on interdependently-structured tasks?*

Answers to research question 1 helped identify individual behaviors and behavior changes. Answers to research question 2 helped to collect evidence to examine team-level behaviors, validate the concept of behavioral interdependence, and explore potential relationships among task structures, members' behaviors, and overall collaboration.

Methods and Procedures

Three SameTime meeting videos were selected for each selected project team to shed light on the dynamics of collaborative, distributed problem-solving of interdependently-structured engineering tasks within a computer-supported collaborative learning environment.

Students' behavior data were analyzed in several phases. In the first phase, the video data were reviewed and rated to gauge students' behavioral interdependence level in the selected meetings. Observation notes were taken during the rating and observation processes. Next, recorded conversations in the selected meetings were transcribed. The written transcripts of the meeting conversations were analyzed on a sentence-by-sentence basis to identify individual student behaviors and their interactions with peers. Attention was focused on communication behaviors, planning activities, and decision-making strategies. Other interesting data, such as students' use of technology and their temporal planning and time use activities were also included and highlighted in the analysis.

Rating, observation, and conversational data were collected and analyzed independently by two experienced researchers. Disagreements in the analysis process were discussed openly until joint agreement was established on conclusions. Behavior data were then combined with peer assessment data and performance data to observe: (1) whether individual students performed differently in disciplinary, technical areas (individual DSTs), (2) whether individual students' behaviors continued (or not) to the end of the course, and (3) potential associations between behaviors and performance. At the end, analysis results were organized in a case-based description. This procedure was most suitable for interpreting and revealing the nature of the study context and actual occurrences in the collaboration processes for each of the selected cases.

Major Findings and Discussion

Study results and findings were detailed in Chapter 4. This section therefore summarizes major findings to address the two research questions and discusses how current study findings are supportive or contrary to previous research.

Research Question 1 *(What individual behaviors were observed in project teams as they were working on an interdependently-structure task? How did individual behaviors affect team performance?)*

Data Summary to Answer RQ1

When working on the same course tasks structured with high interdependence, data suggested that students in team Alpha and Gamma showed varying levels of collaborative behaviors. The varying levels of collaborative behaviors resulted in the two teams' different levels of behavioral interdependence, collaboration, productivity, and performance.

Consistent with previous research findings, a high level of structural interdependence appears to be positively related to students' task-related collaborative behaviors in both teams. The structural interdependence level increased from Lab 1 task (the lab 1 task is structured with interdependence in goals, rewards, technology, and instruction) to the course design project (the design project is structured interdependently in goals, rewards, resources, technology, and instruction). The growing structural interdependence from Lab 1 task to the design project resulted in individual members' increased task-related collaborative behaviors. For instance, similar to Fan and Gruenfeld (1998)'s observation that team members in high resource interdependence mode used more asking, negotiation, explanation, and persuasion, students in both team showed continuously increased participation in behaviors of questioning, suggesting, responding, explaining, and information-sharing.

Nevertheless, the two teams demonstrated different levels of task-related collaborative behaviors, which resulted in two varying levels of behavioral interdependence. Working as a self-managing project team, Gamma students continued to form a high level of behavioral interdependence and stay task-focused. Gamma students learnt carefully about task requirements (well-equipped in context knowledge), developed the team's problem-solving steps, established the team's working and task coordination strategies, conscientiously planned and used their working time, and strived to establish effective information communication. These behaviors have been shown to support collaborative knowledge-making and knowledge co-construction (Kumpulainen & Kaartinen, 2003) and resulted in the team's vigilant decision-making (Fan & Gruenfeld, 1998). Also compatible with previous research that high task interdependence promotes joint efforts to disagreements and conflicts, Gamma students paid attention to misunderstanding, openly discussed conflicts, confusions, and technology issues as a team, and solved conflicts based on knowledge, logical arguments, and explanation; rather than personal feeling. As a consequence, a positive interactional relationship and working morale seemed to be well-nurtured among students along with their collaboration progress. Gamma students' high levels of task-related collaborative behaviors tended to promote collaboration, productivity, and the team's high level performance in the design project.

In contrast, Alpha students were observed to demonstrate fewer task-related collaborative behaviors and a lower-level of behavioral interdependence. Data suggested that Alpha students evidenced a lack of task management and temporal planning strategies. Disruptive behaviors were often introduced and deterred the team from having effective communication and resulted in decreased team collaboration and productivity. Alpha students' approaches to dealing with conflicts were also different from team Gamma students' collaborative approaches. Members were observed to persist in their personal perspectives in team discussions; personal feelings and emotions arouse when the discussion results contradicted personal choices. Consistent with previous research, the intensive interaction required by the high resource interdependence, although creating communication opportunities, seemed to result in more frustration among Alpha students because misunderstanding, conflicts, or technology issues were not addressed in a timely manner.

In addition, individual members in each team demonstrated different behaviors among them and appeared to play some different roles in team collaboration. For instance, both peer assessment and observation data suggested that GL and BZ in Team Gamma and AF in Team Alpha, in addition to their great efforts working in technical areas, participated more frequently in organizing tasks, planning time use, and keeping team structured. Data also revealed that good-performing team can contain poor-performing individuals while poor-performing team can also have good-performing students. For instance, MW in Team Gamma and LS in Team Alpha had poor performance in the individual DST. Poor individual performance in the technical area limited their contribution to the teamwork. In addition, they were reported to have poor time/task management and were often observed to miss meetings, have delays in submitting individual design / analysis pieces to the team, and deliver poor quality work. Their individual behaviors negatively influenced the team performance and other members had to make up the work for them. For instance, data suggested that students who had poor performance in DST tended to take free-rides in teamwork.

Individual behavior differences between the two teams implied other factors that may have been associated with behaviors in a high level structural interdependence task setting.

Discussion: alternative explanations.

(1) Personal skills: *individuals with high levels of knowledge, skills, and abilities do better with task-related collaborative behaviors in highly-structured task settings; individuals with lower levels of knowledge, skills, and abilities are more likely to experience process losses in highly-structured task settings.*

Personal skill level may be a factor that is associated with individual behaviors in complex task settings. Bonner, Hastie, Sprinkle, and Young (2000) stated that "…increase in effort are less likely to translate into improved performance unless individuals possess requisite skill and/or knowledge of appropriate strategies" (p. 22). Highly-interdependent tasks are usually complex and demand high level cognitive skills and self-management abilities (Allen, et al., 2003; Gundlach, et al., 2006; Lembke & Wilson, 1998). Therefore, whether individual team members' knowledge, skills, and abilities, in areas such as communication, technology, and self-management, are compatible with such task contexts may be associated with members' task-related collaborative behaviors in highly-structured task settings.

Highly-interdependent tasks generally pose more cognitive complexity because of "high level of sharing of information required and the need to become familiar with resources owned by other members" (Allen, et al., 2003; p. 734) and of other demands in task-related coordination activities. Consequently, knowledge and skill requirements for achieving such highly-interdependent, complex tasks increase and students need to master appropriate strategies, skills, and knowledge to do each distinctive subtask. However, this is true only if members possess requisite skills and knowledge at the beginning of a task. Otherwise, they tend not to have sufficient time to acquire these skills during the project period, even after a brief learning and practicing period is given (Bonner, et al., 2000). To expect individual members, who are not well equipped with requisite skills for complex teamwork situations, "simply to begin at high levels of collaboration is naïve and ignores the need for progressive learning to occur within work groups" (Geer & Barnes, 2007; p. 135).

When members had inadequate skill preparation, the high level of cognitive complexity demanded by highly-interdependent tasks can result in process losses. Process losses are usually observed as in following situations and confirmed by the data in this study:

(a) When students perceived the task being complex, they usually struggled with learning and performing multiple tasks (e.g., performing effectively, interacting with members, and learning new technology or teamwork skills) simultaneously. Students who are not skillful in communication and self-management (e.g., time management) and used to teamwork settings, learning of new disciplinary, technical knowledge, new communication skills and technology, along with getting themselves familiar with the design problem can be cognitively challenging (Bonner, et al., 2000). Their attention to critical performance requirements tend to be less effective (Allen et al., 2003). By the same token, students who possess better knowledge preparation in disciplinary, technical areas and skills in areas such as communication and management likely become more effective participants in team problem-solving. Consistent with this proposition, Gamma students, on average, had higher individual DST scores than Alpha students. Gamma students' higher individual DST scores confirm that they had better knowledge preparation for the team's design project. Another example is AF in team Alpha. Data suggested that AF appeared to have a good grasp of the technical knowledge in DST and he was observed to lead the team discussion, drive deadlines, and put significant efforts on the team design project, especially in major analysis work. Before AF joined the team, Alpha students were observed to frequently revisit the design project task description and their unfamiliarity with the task requirements is likely to limit their progress in the teamwork.

(b) Consistent with previous research, technology which offer multiple communication opportunities can impose unnecessary distractions and additional learning load to members. Therefore, if the technology cannot be used effectively on task-related activities, they may consume students' cognitive capacity and distract their focus on tasks. Echoing this postulation, Alpha students' use of shared application consumed a large portion of the meeting time and caused frequent communication break-downs, which distracted members' focus on tasks.

(2) Task planning and management behaviors and activities: *high levels of planning activities lead to higher levels of team coordination and task performance than lower levels of these activities*

Janicik and Bartel (2003) defined four component planning activities which include establishing objectives, generating sub-tasks, creating role or task assignments, and discussing about time and temporal issues. Planning activities and organizational behaviors play a critical role in coordinating team members' collaborative efforts as well as regulating the team's problem-solving activities (Lee, Lin, Huang, Huang, & Teng, 2015). The two sample teams were observed to demonstrate different levels of planning behaviors and activities, which seemed to be directly associated with team performance.

Alpha students were not observed to have planned problem-solving activities. Neither did they develop explicit meeting objectives, design steps, or time management strategies. Certain tasks were scheduled in the team's selected meetings; however, meeting agenda were seldom executed thoroughly, which led to several performance deficits such as individual students' participation in task-irrelevant conversations (e.g., social-loafing activities), extension of meeting duration, and failure of completing tasks on a timely manner. These behaviors, due to students' lack of organized planning strategies and attention to time use, may have contributed to the team's low productivity.

Urgent deadlines seemed to play a primary role in intriguing Alpha students to focus more on task-related, promotive behaviors. This observation echoed Marks, Mathieu, and Zaccaro (2001)'s assertion that "time factors, such as project deadlines … dictate many aspects of group functioning, including the strategies that are employed, the pace of activities, and role assignments that develop for the groups to perform successfully" (p. 359). Deadlines 'forced' students to work closely with each other in order to complete the work before the due time. Although Alpha members had the same amount of time as Gamma time, they did not use their time well and consequently devoted less time to necessary interaction; hence, it is very likely that individual Alpha members did not have adequate understanding of each other's work and to figure out the best synergy strategies for the final presentation product. In such situations, students' task-related, promotive behaviors seemed to increase; however, the product quality, resulting from such a short-period of intensive interaction pushed by high time pressure, can be sacrificed. As Janick and Bartel (2003) observed, in their empirical study of 48 college student self-managing project teams who were working on a complex, semester-long task, when teams failed to discuss temporal constraints in their project planning, activities related to task integration "might become subject to severe time pressure as the project deadline approaches, which could lead to suboptimal performance" (P. 124).

In contrast, Gamma students showed distinctive organizational behaviors and time awareness in their planning meeting. Similar to the four planning components suggested by Janick and Bartel (2003), Gamma members developed clearly-defined design objectives and steps, identified and sequenced subtasks, spelled out outcome expectations, and specified schedules for tasks and design steps. As described above, Gamma students' individual behaviors and efforts, such as emphasis on early preparation, being cautious of time use, and being meticulous about task quality, may contribute to the team's high level planning activities, which were further conducive to the formation of team norms emphasizing awareness of and attention to time (i.e., time awareness norm). According to Janicik and Bartel's (2003), high levels of initial temporal planning contribute to the formation of time awareness norms emphasizing attention to time-related issues, which yield long-term positive benefits on effective coordination and project performance. Individual Gamma members were consistently observed to intensively engage in task-related discussions, use time-efficient strategies to facilitate team-work processes, and regularly complete individual and team tasks in a timely manner across three meetings. Consistent with Janick and Bartel's findings, Gamma students may be characterized to have formed a time awareness norm because they were observed to have "the tendency to view time as a scare resource and to plan its use carefully, and include such characteristic as allocating time appropriately and setting schedules and deadline accordingly' (p. 123). Members in such teams are also likely to quickly adapt to unanticipated schedule changes, encourage adoption of time-efficient activities and strategies, and "facilitate self-adjustment in the timing of a given member's activities so that he or she does not adversely affect group coordination and performance" (p. 124). Data confirmed that Gamma students' task-related management and time use behaviors were consistent with Janicik and Bartel (2003)'s research findings.

In addition, individual students' time / task management behaviors can largely influence team work progresses. Because the team design project was composed of members' individual work and individual work pieces were interdependent on each other, individual students' great efforts in completing work on time allowed rest of the team to have time to read and digest shared information before they were able to work on final synthesis. In contrast, individual students' delay in completing individual pieces or submitting poor-quality work usually inhibited the team work progresses and the team may either not be able to continue the design work or have to make up for the person.

(3) ***Self-concept of individualism-collectivism:*** *individualists are more challenged to adapt to the team work than collectivists*

Third, individual members' self-concept of individualism-collectivism may be another factor to affect their participation in task-related collaborative behaviors in teamwork (Gundlach, Zivnuska, & Stoner, 2006; Wagner, 1995). In a team setting, members who possess individualism emphasize individual efforts and are likely to ignore those group interests that conflict with personal interests (Wagner, 1995). When this situation arises, behavioral interdependence suffers (Wageman, Gardner, & Mortensen, 2012). For instance, individualistic members were often reported to be more resistant to teamwork and more likely to have task-focused conflicts because they value independent efforts (Wageman & Gordon, 2005), self-reliance, and recognition (Gundlach et al., 2006) and tend to "retain their own personal perspectives as the center of their attention" (Lembke & Wilson, 1998; p. 929). Individualists were observed to show less collaborative behaviors than members who emphasize group values (Wageman & Gordon, 2005; Wagner, 1995). In contrast, members possessing collectivism accord personal success to their affiliated organizations/teams and value collective efforts and inter-personal relationships. They identify themselves as highly interdependent and such interdependence was significantly conducive to their well-being (Gundlach, Ziynuska, & Stone, 2006). While collectivists focus on group goals, they are more likely to adapt to group settings and share resources with peer members.

Team-identification.

Self-concept of individualism-collectivism was further reported to directly affect members' identification with the team (which is usually referred as team identification) and impact team performance. When introduced into a teamwork setting, individualists usually face more challenges than collectivists to identify themselves as part of a team. Teamwork requires members to transition from "thinking, feeling, and behaving like an individual to thinking, feeling, and behaving like a team member" (Gundlach, et al., 2006, p. 1611). Such transition conflicts with individualists' value of personal efforts and requires individualists to change their habitual independent behaviors; thus, individualists can have more difficulties to achieve this transition compared with collectivists. Individualists may encounter frequent challenges cognitively, emotionally, and behaviorally when facing a series of teamwork activities such as information sharing, coordination, and collective decision-making: members may be emotionally resistant to work with others, cognitively unprepared for different collaborative situations, and behaviorally unskillful in areas such as collaborative communication, collective planning, and team decision-making. Individual team identification then is apparently weak for individualists. For instance, some of Alpha students were observed to persist in their personal perspectives in the group discussion and personal feelings and emotions arouse when the discussion results contradicted with personal choices. Such data may suggest that some of Alpha students have difficulties to transition to team work settings. However, due to the fact that no direct data in the study to support the factor of individualism-collectivism and the concept of team identification, the description of these factors in this section is for discussion purpose.

As a summary, the two teams showed different levels of task-related collaborative behaviors. Individual members within each team also appear some behavior differences. Current study findings confirmed previous research that factors such as personal knowledge preparation and skills in task management and temporal planning may explain behavior differences of students in the two teams.

Research Question 2 (*What patterns of team behaviors were observed in project teams as students were working on highly-interdependent tasks? How did team behaviors pattern change and affect team performance?)*

Data Summary to Answer RQ2

Team Gamma students showed consistent behaviors across the three time intervals. As a team, they maintained tightly-connected communication flow, near 100% response rates, organized task-related discussion and problem-solving sequence, high level of mutual understanding of shared information, clear understanding of tasks and task requirements, well-formed time awareness, and carefully-planned project working steps. Their highly-motivated working momentum continued and grew stronger from Lab 1 meeting, their initial collaboration at the early stage of the semester, to the selected project working meeting at the late stage of the semester. Team Gamma students' behavioral interdependence level increased (behavioral interdependence score increased from 89% in Lab 1 meeting to 96% in selected project planning meeting) and maintained at this high level (average interdependence score from the three selected meetings was 93.7%). Team Gamma's high levels of task-related collaborative behaviors (i.e., behavioral interdependence) are likely to contribute to the team's enhanced team collaboration, increased meeting participation, high working momentum and productivity, and continuation of high levels of collaboration. Continuation of high levels of task-related collaborative behaviors also tend to result in team's increased success in achieving high quality work.

In contrast, as a self-managing project team, team Alpha was observed to have frequent broken communication flow, sometimes participate in task-unrelated activities and conversations, and lack mutual understanding and awareness of task requirements. The team's discussion sequences were random and unorganized and personal feeling and emotion aroused during the discussion process further impacted the team decision-making. The team's moderate interdependence scores continued from Lab 1 (74%) to its selected project planning meeting (74%) and slightly increased to 81% in its project working meeting. The team's average behavioral interdependence score was 76.3%. Team Alpha's low-moderate levels of behavioral interdependence are likely to contribute to the team's decreased productivity and discouraged working morale.

Discussion: alternative explanations.

(1) ***Behavior inertia:*** *Good behavior inertia supports a team's focus on task-related challenges; whereas bad behavior inertia deters the team from achieving optimal performance.*

Consistent with previous research, both Alpha and Gamma teams seem to follow the rule of habitual behavior / behavior inertia that a team's initial behavior plays a primary role in affecting the team's following behaviors. Once a certain behavior pattern (e.g., time awareness, technology use) was established, it tended to persist simply because of inertia or the anticipated costs of change (Gersick & Hackman, 1990).

Research on habitual behaviors / behavior inertia has been observed across different disciplines (Geer & Barnes, 2007; Gersick & Hackman, 1990; Huysman, Steinfield, Jang, David, Huis, Poot, & Mulder, 2003). Researchers studying the team attentional process suggest that the persistence of a team's initial behaviors in their following behaviors was due to priming effect (Hinsz, Tindale, & Vollrath, 1997), which is referred to as "when certain types of information are primed early in a group's life, members are highly sensitive to such information in subsequent tasks or events" (Janicik & Bartel, 2003; p.124). Another reason proposed by Gersick and Hackman (1990), who explained the existence of behavior inertia, was that simply changing the routine itself is anxiety arousing. It is especially anxiety-raising when a team faces task completion deadlines and members lacked interest in or attention to challenging the existing routines and experimenting with new ways of communication, coordination, or problem-solving (Geer & Barnes, 2007). Therefore, a team is rarely observed to "spontaneously initiate changes or improvements in its established habitual routines" (Gersick & Hackman, 1990; p. 79). Consistently, behavior patterns of both teams, in communication, planning, technology use, and decision-making, were observed to continue and grow stronger in this study.

Habitual behaviors have both functional and dysfunctional consequences to team performance. One advantage of habitual behaviors is that once behaviors become habitual routine, they save members' time and energy on team coordination and allow them to focus on task-related challenges. When a habitual routine is well exercised, the team's time and energy required to coordinate in executing behaviors can be kept low (Gersick & Hackman, 1990). For example, team Gamma's organizational behaviors were observed to decrease in the project working meeting. This is probably because the team had established habitual routines in organizing task coordination, problem-solving approaches, and time use in their planning activities at the early stage of the design project. Because such organized habitual routines were beneficial to team functioning and performance, researchers might suggest that it is better that the team will continue with these behavior habitual routines for the benefit of the team (Geer & Barnes, 2007; Gersick & Hackman, 1990). Students were also observed to have formed habitual behaviors in using technologies in collaboration and such inertia in technology use is also called media-stickiness. In this study, Gamma team's consistence in choosing basic communication tools can be a good example of the team's "inertia" behaviors in technology use. The team ignored other technology resources with additional features in favor of media that was familiar and working effectively early in the team’s activities. Team Gamma’s inertia behaviors in technology use can also be beneficial to team performance. In Geer & Barners (2007)’s study of media stickiness behaviors in CSCL settings, the authors argued that “learning beyond the initial effective use of the technologies and orientation is not necessary and inertia is a valuable aspect of the working group” (p. 134) because such inertia behaviors can save time and keep a team to stay focused on task-related problem-solving activities.

In addition, familiar, well-practiced habitual routines in teams can reduce the uncertainty and anxiety that is often observed in complex, collective work settings, as well as foster members’ comfort with the team. Following the same logic, habitual routines which are not functioning well on collaboration and performance may continue deterring the team from achieving optimal performance. Since the early establishment of habitual routines were sometimes not realized by team members (invisible) and teams were rarely observed to “spontaneously initiate changes or improvements in its established habitual routines” (Gersick & Hackman, 1990; p. 79), the dysfunctional, harmful consequences of these habitual behaviors would continue. For example, team Alpha’s behaviors of unorganized coordination of meeting discussion and management of time use continued across the three meetings. Although Alpha students were observed to stay more focused on design tasks in the project working meeting, they were still observed to have low ability to control their time use. Alpha students were unable to complete scheduled tasks within meeting periods and regularly scheduled additional meetings to work on unfinished tasks. Such poor problem-solving behaviors and temporal management approaches discouraged students from obtaining good time management experiences and were ultimately detrimental to the team’s performance.

(2) ***Team identity:*** *higher levels of team identity may support team conflict management and lead to optimal team performance; lower levels of team identity may result in poor team conflict management and performance.*

Inspired by the aforementioned idea that a person's team identification may be associated with his/her behaviors in a team setting, the concept of team identity is likely to be related to team-level behavior differences. Team identity is based on the individual level of team identification. Team identification decides an individual member's emotion and psychological status when introduced to a team task setting. Team identity is a collective construct which accounts for perception of oneness as a team across all team members. Therefore, individual students' high levels of team identification lead to a team's high team identity level. As noted above, team identity plays a critical role in highly-interdependent task setting and has been reported to significantly moderate team cooperative conflict management and performance in high task interdependence settings (Somech, Desivilya, and Lidogoster, 2009). The potential association between team identity and a team's performance in conflict management and performance is probably because that, when the team identity level is high, members feel strong that the team is one unity and they are part of the team; consequently, such strong team identity promotes deindividuation (Blader & Tyler, 2009). Hence, members are more likely to put team and others' interests above their personal interests, to resist distraction from achieving the team goal, and to stay more focused and exert their efforts for the benefit of the team. Further, the team members are also more likely to pay attention to conflicts and issues and work together to conquer difficulties and conflicts when handling high levels of cognitive demands required from the task and high stress from the time constraint (Somech, et al., 2009). For example, Gamma students (especially GL, BZ, and BK) consistently stayed task-focused and presented a high level of collective effort. Such team behavior pattern may be associated with a high level of team identity. In contrast, Alpha students were observed to have emotional responses when the team discussion resulted in conflict with their personal choices and sometimes engage in social-loafing activities. Although Alpha students seemed to engage in more prosocial behaviors, individual members' collective efforts on task-related activities within the meetings were relatively weak, especially during the first two meetings. These types of behaviors may be associated with a low level of team identity and suggested that Alpha students, on average, may not have high levels of team identification. As noted above, due to the fact that there is no direct evidence to support the concept of team identity, the description of this factor is for discussion purpose.

As a summary, although the two teams presented different levels of task-related collaborative behaviors, both teams were likely to follow habitual inertia. Team behavior patterns tended to continue and grow stronger along with their collaboration process. As team tasks' interdependence structure grew stronger and tasks became more cognitively challenged, teams were observed not to change their behaviors. In terms of team behavior differences, previous research suggested that team identity, the sum of team members' team identification, may be a factor to be associated with behavior differences between the two teams.

Overall, the current study confirmed that behavioral interdependence was positively associated with a task's structural interdependence level in general. Task-related collaborative behaviors increased with the increment of a task's interdependence level. Evidence also suggested that teams followed the rule of habitual behaviors/behavior inertia during their collaboration process. Consistent with previous research, high levels of structural interdependence resulted in process losses, teams with students who were not adequately prepared in skills and ability faced cognitive, emotional, and behavioral challenges in such task contexts. Data suggested that planning, especially temporal planning and awareness, was critical in organizing a team's problem-solving activities and contributed to team functioning and performance. Students' demonstration of different behaviors when working on the same tasks suggested that there may be other factors associating with behaviors in high structural interdependence task settings. Exploration of these potential factors include individual knowledge and skill preparation for team settings and individual effective temporal planning and task management activities. Based on previous research, self-concept of individualism-collectivism may also be associated with team behavior differences and was described in this section for the discussion purpose.

Future Research and Recommendations

This study explored the concept of behavioral interdependence by examining, describing, evaluating, and comparing task-related collaborative behaviors between the two college student engineering project teams. The results of this study validate the concept of behavioral interdependence through providing a thorough description of members' behaviors, strategies, and activities when they participated in communication, planning, and decision-making in the collaborative, problem-solving processes. Findings resulted from this study are insightful to the field of instructional design:

First, findings confirmed the importance of task structure in inducing and encouraging collaborative behaviors and documented the formation and evolution of behavioral interdependence as the two teams worked through tasks in a semester. Moreover, the study evidenced that the formation of behavioral interdependence is a dynamic process and can be strengthened or weakened with individual behavior changes or when other factors enter. For instance, Gundlach et al., (2006) suggested that the intensive communication demanded by high task interdependence requires team members to spend time and energy working together, which encourage individual levels of identification with the team regardless where they stand on the individualism-collectivism continuum. Therefore, introducing appropriate scaffolding strategies (e.g., providing built-in scripts to suggest specific probing questions for effective information sharing) when certain behaviors need to be modified / suggested for the benefits of good teamwork. However, choosing the right timing is critical and introducing the intervention early may be more effective than later before certain behaviors are saturated in teamwork routines and become habitual. Introducing the intervention early tends to lessen the cost and lower members' anxiety level therefore new behaviors are more likely to be built in. Providing timely feedback may also be necessary to lessen members' anxiety when facing changes and encourage behaviors that are beneficial to team functioning.

Second, existing research and current study findings suggested that high levels of structural interdependence may introduce complexity, which could result in process losses and performance deficit (i.e., people who know the appropriate skills but do not perform them (Gable, Quinn, Rutherford, Howell, & Hoffman, 2000)). Data suggested that individual students' performance in DSTs (the disciplinary, technical trainings) tended to closely associate with their performance in teamwork. Therefore, for those poorly-performed students in DSTs (e.g., MW in team Gamma and LS in team Alpha had poor individual performance in DST), extra attention is suggested to understand reasons of their delayed learning and certain scaffolding strategies are necessary to support these poorly-performed students' learning development and participation in the collaborative setting. Data also suggested that students who had poor performance in the DST technical areas tended to take free-rides (e.g., MW in team Gamma barely worked on his analysis and BK, who was in the same DST track as MW, did all the FEA analysis work). For those students, extra efforts may be needed to understand reasons behind their behaviors. Potential reasons can be due to their poor content knowledge foundation, bad time management, and task design "flaw" which can offer students, who had weak technical knowledge, opportunities to take the free ride. For instance, Hackman and Wageman (2005) suggested that "well-composed teams are as small as possible given the work to be accomplished…and consist of a good mix of members – people who are not so similar to one another that they duplicate one another's resources…" (p. 60). Teams in the CED course were composed of two students who were in AS (Aerospace DST) and two students were learning FEA (Finite Element Analysis DST). The two students who were at the same DST track shared same resources and such task/team design can create opportunities for free-rides. Therefore, in future instructional design in similar learning settings, designers should carefully avoid similar issues.

Literature has supported that how students perceive the use of tools can influence their choice and use of specific tools (Bower, 2008; Jeong & Hmelo-Silver, 2016). Students' perceived usability of a tool can have some differences from the tool's actual utility based on the designers' intention. For instance, Alpha students may perceive shared screen possesses similar functions as interactive whiteboard that both tools offer members to work collaboratively on a same document. However, Alpha students may not realize that screen sharing demands more bandwidth and using it can reduce the quality of audio and video transactions. In such circumstances, appropriate scaffolding strategies may be needed such as providing students short description to inform differences between the two tools that share similar functions, suggesting situations that each tool best fits, and prompting brief scripts to help students choose a more effective tool to fit their communication and design needs. Such scaffolding strategies can help reduce students' cognitive load when they need to make quick decisions in choosing tools. In future research, technology affordance factor also needs to be included to expand the boundary of this study.

Course designers or instructors may also collect information related to students' self-perception of individualism-collectivism and choose suitable strategies to ensure effectiveness of intention to intervene in the ongoing collaboration process, challenge individualism, and encourage skill development and emotional attachment to a complex team setting. For instance, Gundlach et al. (2000) suggested that "rather than immediately focusing on big picture team outcomes, focusing more on rewarding specific team-oriented behaviors and intermediate outcomes – such as sharing information, giving and responding to feedback appropriately, and meeting incremental deadlines and quality standards – will encourage behavioral alignment, a crucial component of team identity and precursor to optimal team performance" (p. 1625).

In addition, previous research suggested several learner characteristics can influence learners' behaviors and performance in CSCL teamwork settings, such as levels of prior knowledge, working memory capacity (Knorzer, Brunken, & Park, 2016; Schwaighofer, et al., 2017), communication styles, and pre-existing friendship (e.g., Cho, Gay, Davidson, & Ingraffea, 2005). For instance, literature suggested that learners who possess high prior knowledge are more likely to identify relevant information from the text, connecting new information with existing scheme (Schwaighofer, et al., 2017), and therefore have more cognitive resources available to handle extraneous load components in complex learning settings. For this reason, individual characteristics data, such as prior knowledge, can be collected at the beginning of the course so that necessary scaffolding strategies can be designed and provided to fit different learning needs in the following instruction process. Current study also needs to be expanded to include these learner characteristic factors into consideration in future research.

Third, current study findings suggest that planning and organizational activities, especially members' temporal planning behaviors and awareness, are likely to have strong associations with effectiveness and productivity of a team's problem-solving. Considerable technical support and scaffolding strategies are therefore suggested to make available to members who "are not already knowledgeable, skilled, or experienced" (Hackman & Wageman, 2005, p. 61) in areas such as self-management, planning, and communication and are willing to hone these skills to succeed in complex teamwork settings. In addition, suggesting a leader may be an appropriate approach for teams who lack structures and do not have effective temporal and task management practices (e.g., Alpha). Data suggested that GL and BZ (in team Gamma) had strong organizing skills in temporal planning and task management and they played important roles in 'leading the team in the right direction' and 'holding the team together' so that the team continued to keep their structure. The leader can be selected from members who had shown certain leadership traits such as time awareness, good task management skills, and expending great efforts in individual learning and teamwork. The leader can hold responsible for the group and help members minimize coordination problems (Hackman & Wageman, 2005). Timing of when to suggest a leader is sensitive to the degree of team readiness. Hackman and Wageman (2005) pointed out interventions are likely to be helpful only if they are provided at a time when the team is ready for them. By readiness, the two authors mean that (1) the issue is obvious to a degree that team members realize they need a change and (2) the degree to which the team is not at the time facing compelling matters (e.g., approaching deadlines). Mid-point of team collaboration can be an appropriate time to consider for appointing a new leader. This is because (1) both instructors and individual students become familiar with team members and are likely to understand each person's strengths and efforts in individual learning and teamwork, such as who possesses strong technical knowledge or emphasizes team structure and (2) literature suggested that "at the midpoint, when the team has completed about half its work (or half the allotted time has elapsed), it is especially open to interventions that help members reflect on their task performance strategy" (Hackman & Wageman, 2005, p. 65). Further, extra attention to the balance between task complexity level and time pressure (Allen, et al., 2003) may ensure members adequate time to learn the new knowledge and skills and practice these skills in tackling multiple problem-solving challenges at the same time. Last, more research may be conducted in areas such as how personal skills in time management relate to team temporal planning and how personal skills in independent work can be better transitioned to team settings.

Based on study findings, recommendations suggested to improve the design practice of this course are summarized in Table 5-1.

Table 5-1

Summary of Recommendations Based on Study Findings

Study findings	Recommendations
Behavioral interdependence describes a dynamic process of collaborative behavior changes in teamwork and can be strengthened or weakened with individual behavior changes or when other factors enter (Team behaviors tend to follow the rule of behavior inertia)	• Introducing appropriate scaffolding strategies to encourage task-related team-level communication (e.g., providing built-in scripts to suggest specific probing questions for effective team-level information sharing) when certain behaviors need to be modified or suggested for the benefit of good teamwork ○ Choosing the right timing is critical and introducing intervention strategies early may be more effective than later before certain behaviors are saturated in teamwork routines and become habitual ○ Providing timely feedback may be necessary to lessen members' anxiety levels when facing changes and to encourage behaviors that are beneficial to team functioning
Individual members demonstrated different levels of task-related collaborative behaviors: high levels of structural interdependence, although created more communication opportunities, may introduce complexity, which could result in process losses and performance deficit (Individual performance in DSTs tended to positively associate with student participation in teamwork)	• Seeking reasons of those poorly-performed students' delayed learning and task-unrelated behaviors (e.g., free-rides) and providing appropriate scaffolding strategies ○ Examining whether there is task-design flaw which may create opportunities for free-rides • Providing appropriate scaffolding strategies to assist students' selection of and effective use of given tools and help reduce students' cognitive load in making technology decisions • Collecting individual characteristic data at the beginning of a course (e.g., prior knowledge) so that necessary scaffolding strategies can be designed and provided to fit varying learning needs ○ Collecting information related to students' self-perception of individualism-collectivism and choose suitable strategies to ensure effectiveness of intervention that promotes team-identification in the ongoing collaboration process such as focusing more on rewarding specific team-oriented behaviors rather than on a big picture of team outcomes. Specific team-oriented behaviors include behaviors such as sharing information, giving and responding to feedback appropriately, and meeting incremental deadlines and quality standards

Study findings	Recommendations
Effective temporal planning and task management activities are likely to have strong associations with team collaboration and performance	• Considerable support and scaffolding are suggested to make available to members who are not knowledgeable and skillful in areas such as self-management and temporal planning in complex teamwork settings • Suggesting a leader for poorly-managed teams o Timing of suggesting a leader is sensitive to the degree of team readiness: leader may be selected during the mid-point of team collaboration and from team members who have shown certain leadership traits such as good planning or task management skills, time awareness to meet deadlines, and expending great efforts in individual learning and teamwork. • Extra attention to the balance between task complexity level and time pressure may ensure members adequate time to learn the new knowledge and skills and practice these skills in tackling multiple problem-solving challenges at the same time • More research is suggested in areas such as how personal skills in time management relate to group temporal planning and how personal skills in independent work can be better transitioned to team settings

To conclude, structural interdependence is a strong factor to encourage learners' task-related collaborative behaviors and predict behavioral interdependence to be formed in the actual collaboration process in such complex learning settings. However, both data and literature suggested that, in addition to the influencing effects of task interdependent structural features, several factors are likely to associate with members' participation in task-related collaborative behaviors and engagement in teamwork. These factors include learners' performance in DSTs, planning skills and activities, and other potential individual characteristics such as learners' perception of individualism-collectivism. For this reason, the Interdependence Categorization Chart presented above in Chapter 2 is revised and updated to the figure presented below (Figure

5.1). This new figure is named Interdependence Categorization and Description Model and is mainly used to describe structural interdependence and behavioral interdependence, and connect the two interdependence in teamwork. The left side of the model, also named Interdependence design of collaboration, is structural interdependence and its sub-category interdependence. The right side of the model, also named Actual occurrence in collaboration, is behavioral interdependence and includes behavioral interdependence in achieving outcomes and completing tasks. In the middle of the model, four people icons are used to represent learners who enter such complex, structurally-interdependent task settings. Different colors of people icons mean that learners are with different backgrounds and from different disciplines. People icons also imply that individual learners are important factors in collaboration and learners' individual characteristics may influence the collaboration process, behaviors, and hence behavioral interdependence. The new Interdependence categorization and description model (Figure 5.1) help (1) identify and distinguish the two major interdependence variables (i.e., structural interdependence vs. behavioral interdependence, (2) specify forms of interdependence under the two major interdependence variables, (3) differentiate interdependence designed (i.e., structural interdependence) from interdependence actually formed (i.e., behavioral interdependence) and (4) highlight that learners are the core of collaboration therefore learners' characteristics play significant roles in deciding their actual task-related collaborative behaviors, participation, and performance.

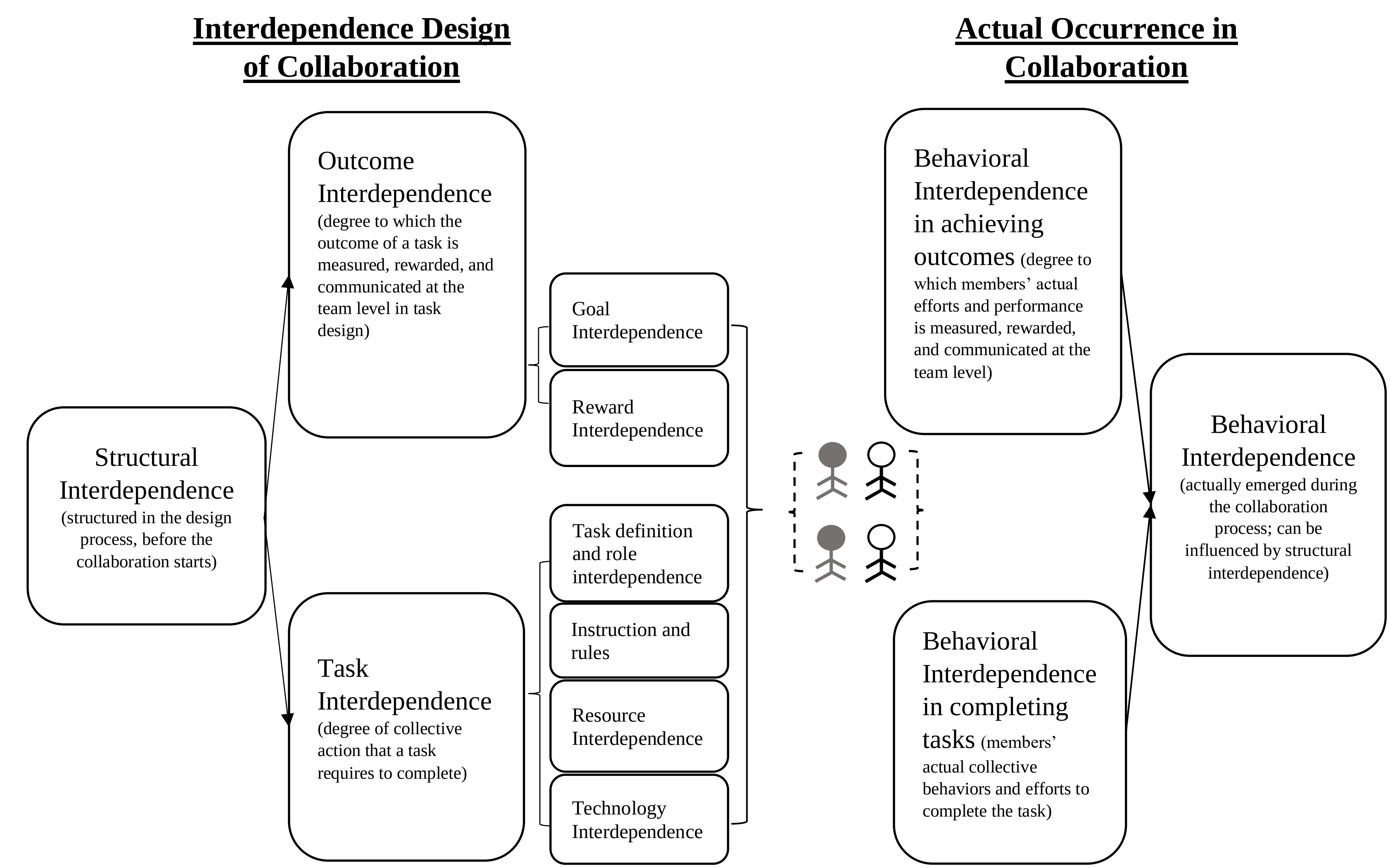


Figure 5. 1. Interdependence categorization and description model.

Limitations

First, this is a case study to investigate two instances in the context of highly-structured task settings within a distributed, collaborative environment. The primary purposes of this study were to create rich, thick description of members' actual collaborative behaviors, validate the concept of behavioral interdependence, and to explore possible association between students' task-related collaborative behaviors (i.e., behavioral interdependence) and team performance. Therefore, no causal relationship can be drawn from this study. For instance, the motivational effect of reward contingency cannot be tested, neither can separate effects of different structural interdependence (i.e., task interdependence vs. outcome interdependence) be confirmed.

Second, this study examined existing data and documents after the course was completed. Direct observation is the primary data collection method. Since there is no access to students when the course was completed, no interview was permitted and no student perception data are available to understand some of the complexities in student behaviors during the observation process. Besides, it is not clear, in all cases, about reasons why students may have made certain decisions. For instance, it is not certain the reasons that personal emotion arouse are due to feelings of being forced, being not interested, being not used to the team setting, or being too overloaded. Although perception data are not available, observation and rating data collected and used in this study were able to create straightforward and critical behavioral evidence for the study purposes. Peer assessment data also offered supplement evidence to examine individual behavior changes. Further, by using certain strategies, such as use of two raters to analyze data independently, observation and rating data produced more objective evidence compared with self-reported perception data.

Third, selection of sample videos was limited to meetings which were recorded and videos that were able to be reviewed. Due to these reasons, no videos were selected in the fourth interval of the course (the period during which teams were working on the final design product). Therefore, some evidence may have been missed. However, according to the theory of habitual inertia, individual participants and teams' behaviors usually settle in the first 60-70% of the team collaboration. Therefore, the sample videos selected randomly in the first 3 course intervals should be able to provide sufficient information to observe whether individual / team behaviors settled (or not). In addition, peer assessment data, collected twice toward the end of the course, offered supplementary information regarding members' contribution to the team. Peer assessment data, although cannot yield detailed behavior information, reflect individual members' (behavior) efforts to the team.

Fourth, as described above, the two teams selected for this study were used in the previous research of the course. Use of the same teams, although helping to build holistic evidence to understand students' dynamic collaborative behaviors and team performance, may bring in bias during the data analysis process due to my preconception of the two teams. To avoid this bias, another researcher was recruited and the two researchers worked independently during the data collection and analysis processes. Besides, procedures, such as triangulation and double-coding, were implemented, to ensure data validity.

Regardless of these limitations, this study is important. Anchored in real collaborative design tasks, this case study resulted in a rich and holistic description of students' collaborative problem-solving behaviors. The results of this study confirmed findings in my prior two studies including: (1) students who had better knowledge in disciplinary, technical areas engage more in teamwork. These students tend to be more confident, conversant, and prepared, often raising good questions, and less engaged in the off-task activities and chatter (Wu & Koszalka, 2011), (2) individual students' insufficient preparation in analytical skills and skills on using specific technical programs inhibited their performance in the design project (Koszalka.& Wu, 2010), and (3) communicating newly-learned DST technical knowledge to team members were challenging and required detailed explanation. The results of this study also expanded findings in the prior studies by offering insightful, detailed empirical evidence to advance the knowledge base of the fields of collaborative learning and instructional design. Based on these findings, future intervention research are highly recommended, such as designing suitable scaffolding strategies that will help team members fully develop skills and work effectively in team activities and enhance members' experience with the high-interdependence structured tasks.

Conclusion

As the essential feature of collaboration, interdependence describes the interactive dynamics among team members during the teamwork process. The level of interdependence emerging from members' behaviors and interaction with each other reflects a team's effectiveness in team communication, task coordination, time management, and decision-making.

In this study, I described project team students' behaviors when they were distantly working together on interdependently-structured engineering tasks within a computer-supported collaboration environment. The concept of behavioral interdependence was selected as the analytical concept. The concept is validated and described through theoretical reasoning and empirical data collected in this study. The study evidenced that successful collaboration is reflected in a team's high level of behavioral interdependence in communication, planning, and problem-based decision-making.

The concept of behavioral interdependence was further confirmed to be an important concept to understand the collaboration process. This study aimed at micro-level investigation of students' behaviors and activities during their problem-solving process on a moment-by-moment basis at the episode level. By using the descriptive case study approach, such micro-level analyses can deepen current understanding of the dynamic evolution of collaborative behaviors and how members' behaviors influenced and were influenced by other's behaviors and how members' behaviors interplay to affect a team's performance. Such analyses also help to identify key behavior elements in a project team's collaboration process, such as temporal planning and awareness. The study confirmed that the same task interdependence does not necessarily induce a same level of behavioral interdependence between teams. Based on current study findings and previous research, several factors were discussed that may be associated with teams' behavior differences in the collaborative engineering design (CED) environment in this study: individual students' knowledge and skill preparation for complex, collaborative design project, effectiveness of team planning and management activities, team behavior habitual inertia, and self-concept of individualism-collectivism. Recommendations therefore are provided including (1) Timing of introducing behavior interventions: providing timely feedback to students' behaviors. When certain behaviors need to be modified, early introduction of behavior intervention (e.g., training of effective team communication skills) is likely to ease members' anxiety level when facing challenges of behavior changes; (2) Instructional support to students who poorly performed in disciplinary, technical areas (i.e., DST in this study): carefully evaluating task features and participants' learning of knowledge (in disciplinary, technical areas) in the middle of the course; being careful with task features that may provide opportunities for free-ride behaviors. Extra attention is suggested to understand reasons of students' learning delay and tutoring may be necessary to promote their learning development and encourage participation in teamwork; (3) Instructional support to students who are not knowledgeable and/or skillful in team planning and management: training support in planning and management is suggested to make available to these members who do not possess sufficient knowledge and skills in these areas; suggesting a leader for poorly-structured/managed teams and choosing mid-point of team collaboration may be an appropriate time for this intervention; carefully evaluating task complexity and time required/pressure and ensuring members to have adequate time to learn the new disciplinary knowledge and technical skills and practice these skills in tacking collaborative design challenges at the same time; and (4) Instructional support to nurture students' team identification: collecting information related to students' self-concept of individualism-collectivism at the beginning of the course; choosing suitable strategies to encourage individual-level team identification such as focusing on rewarding specific team-oriented behaviors .

Current study is significantly valuable to the field of instructional design. It evidenced the dynamics process of team collaboration and captured individual students' detailed behavior and interaction changes along with time and task structure changes. Such descriptive information confirmed with previous research findings and reflected certain potential design issues that may exist in the course. By using the same research methods, more research is suggested in other disciplinary contexts (e.g., sciences, social sciences, healthcare, business, and etc.) where collaboration is frequently used in the workforce. By doing so, the design recommendations generated in this study can be further validated.

Appendix A. IRB Approval Letter

SYRACUSE UNIVERSITY
Institutional Review Board
MEMORANDUM

TO:	Tiffany Koszalka
DATE:	November 14, 2013
SUBJECT:	**Determination of Exemption from Regulations**
IRB #:	13-354
TITLE:	*Team Collaboration in College Engineering Students' Problem Solving: Interdependence and Convergence in a Dynamic Distributed Virtual Learning Environment*

The above referenced application, submitted for consideration as exempt from federal regulations as defined in 45 C.F.R. 46, has been evaluated by the Institutional Review Board (IRB) for the following:

1. determination that it falls within the one or more of the five exempt categories allowed by the organization;
2. determination that the research meets the organization's ethical standards.

It has been determined by the IRB this protocol qualifies for exemption and is assigned to category **4**. This authorization will remain active for a period of five years from **November 11, 2013** until **November 10, 2018**.

CHANGES TO PROTOCOL: Proposed changes to this protocol during the period for which IRB authorization has already been given, cannot be initiated without additional IRB review. If there is a change in your research, you should notify the IRB immediately to determine whether your research protocol continues to qualify for exemption or if submission of an expedited or full board IRB protocol is required. Information about the University's human participants protection program can be found at: http://orip.syr.edu/human-research/human-research-irb.html Protocol changes are requested on an amendment application available on the IRB web site; please reference your IRB number and attach any documents that are being amended.

STUDY COMPLETION: Study completion is when all research activities are complete or when a study is closed to enrollment and only data analysis remains on data that have been de-identified. A Study Closure Form should be completed and submitted to the IRB for review (Study Closure Form).

Thank you for your cooperation in our shared efforts to assure that the rights and welfare of people participating in research are protected.

Tracy J. Cromp

Tracy Cromp, M.S.W.
Director

Note to Faculty Advisor: This notice is only mailed to faculty. If a student is conducting this study, please forward this information to the student researcher.
DEPT: Instructional Design, Development & Evaluation, 330 Huntington Hall **STUDENT:** Yiyan Wu

Office of Research Integrity and Protections
121 Bowne Hall Syracuse, New York 13244-1200
(Phone) 315.443.3013 ♦ (Fax) 315.443.9889
orip@syr.edu ♦ www.orip.syr.edu

Appendix B. Course Schedule

CED' 06 Course Schedule for September 12 – November 7

Class No.	Day & Date	Meeting Type	DLCs: University A – 246 Link Hall University B – 162 Hollister	*DESIGN STUDIO (AIDE): University A – 200 Link Hall University B – 452 Hollister*
5	TUESDAY 9/12	*LAB 1: Conduct 35 minute ST mtgs with each team.*		1:25-2:00 Teams α and β 2:05-2:40 Teams γ and δ 2:45-3:20 Team λ
6	THURSDAY 9/14	**DST1**	**Finite Element Analysis**	**Aerospace Structures**
7	TUESDAY 9/19	**LAB 2:** Conduct 35 minute ST mtgs with each team.		1:25-2:00 Teams λ and δ 2:05-2:40 Teams γ and β 2:45-3:20 Team α
8	THURSDAY 9/21	**Full class lecture.** Lab 1 survey due today!	**Full class lecture**	
9	TUESDAY 9/26	**DST2**	**Aerospace Structures**	**Finite Element Analysis**
10	THURSDAY 9/28	**Full class lecture.** Lab 2 survey due today!	**Full class lecture**	
11	TUESDAY 10/3	**DST3**	**Aerospace Structures**	**Finite Element Analysis**
12	THURSDAY 10/5	**Full class lecture.**	**Full class lecture**	
	TUESDAY 10/10	**No Class (University B Fall Break)**		
13	THURSDAY 10/12	**DST4**	**Aerospace Structures**	**Finite Element Analysis**
14	TUESDAY 10/17	**Time to work.** Coaches spend 35 minutes with each team, during which time teams present their plans from here until PDR (2 slides). Teams work for the remaining time.	Team members may use either location (DLC or design studio)	
15	THURSDAY 10/19	**DST5**	**Aerospace Structures**	**Finite Element Analysis**
	TUESDAY 10/24	**No Class (Eid Ul-Fitr)**		
16	THURSDAY 10/26	**Full class lecture.** Survey 3 due today!	**Full class lecture**	
17	TUESDAY 10/31	**Time to work** plus time in DLCs for practice PDR.	1:25-1:50 Team α 1:55-2:20 Team λ 2:25-2:50 Team γ 2:55-3:20 Team δ	**Team Meetings**
18	THURSDAY 11/2	**Time to work** plus time in DLCs for practice PDR.	1:25-1:40 Team δ 1:45-2:00 Team γ 2:05-2:20 Team λ 2:25-2:40 Team α	**Team Meetings**
	Monday 11/6 Noon	**PDR Powerpoint reports due (20 slides maximum, each slide annotated)**	Post to your **team's** dropbox	
19	TUESDAY 11/7	**PDR Oral Reports**	**Attendance Required**	

CED '06 Course Schedule November – December

Day & Date	**Meeting Type**	**DLCs:** **University A – 246 Link Hall** **University B – 162 Hollister**	*DESIGN STUDIO (AIDE): University A – 200 Link Hall University B – 452 Hollister*
MONDAY 11/6	**PDR Powerpoint reports due at noon to team dropboxes.** 20 slides maximum, each slide annotated, structured like a standard technical report. Must explicitly indicate contributions of various team members.		
TUESDAY 11/7	**PDR Powerpoint presentations due at noon to team dropboxes.**		
TUESDAY 11/7	**PDR Presentations**	**Attendance Required**	
TUESDAY 11/7	**On-line Peer/Self 1 Survey and (separate) "Survey 4" made available today.**		
THURSDAY 11/9	**Time to work.**	Team members may use either location (DLC or design studio)	
THURSDAY 11/9	**Peer/Self 1 and "Survey 4" due by midnight.**		
TUESDAY 11/14	**PDR Feedback.**	**Full class lecture**	
THURSDAY 11/16	**Time to work.**	Team members may use either location (DLC or design studio)	
TUESDAY 11/21	Dr. Charlie Camarda lecture	**Full class lecture (see "Announcements" for more detail)**	
THURSDAY 11/23	**No Class (Thanksgiving Break**)		
TUESDAY 11/28	CDR Info and other important information **Bring your tablets to complete the final survey during class time.**	*Full class lecture, attendance required*	
THURSDAY 11/30	**CDR Practice. Similar to PDR practice on 11/2/06, CDR presenters should have an early draft of their slides or something else to talk about posted to your team space.**	1:25-1:40 Team δ 1:45-2:00 Team λ 2:05-2:20 Team γ 2:25-2:40 Team α	Team meetings/Time to work
MONDAY 12/4	**CDR Powerpoint presentations due at noon to team dropboxes.**		
TUESDAY 12/5	**CDR Presentations**	**Attendance Required**	
TUESDAY 12/5	**On-line Peer/Self 2 Survey made available today.**		
TUESDAY 12/12	**CDR written reports due to team dropboxes. (30 pages maximum; by midnight is acceptable)**		
THURSDAY 12/14	**On-line Peer/Self 2 Survey due no later than midnight.**		

Appendix C. The Group Work Evaluation questionnaire (GWD) (Lin & Laffey, 2006)

FACTOR 1 – Individual Accountability

We each share a portion of the group work.

We participate equally in this group project.

We contribute equally to this group project.

How effective was your group in working together.

I feel my group members are responsible for this group project.

I feel I can accomplish this group project alone.

I feel overall our group cooperates well in this project.

I feel that I must work collaboratively with my group members to complete this group project.

I feel less anxiety and stress working with the group on this project.

FACTOR 2 – Promotive Interaction

We are committed to the group project.

We share necessary materials and information with each other.

We act in a trusting manner.

We help each other out whenever necessary while working on the project.

I feel that we depend on each other while working on this group project.

Our group members' actions/behaviors have an impact on my work.

FACTOR 3 – Intellectual Nature of Co-Construction

We challenge each other's ideas or reasoning, so as to come up with better solutions.

We are not afraid of challenging each other's opinions and raising different ideas.

Appendix D. Communicative functions (Source: Kumpulainen & Kaartinen, 2003)

Category	**Description**	**Example**
Informative	Provides information	“We are supposed to use faces that are of different size.”
Argumentative	Justifies information, opinions, or actions	“But they’re not attached to each other…look, because there we should use a kind of a flap.”
Reasoning	Reasons in language	“Here we have three triangles of equal size.”
Evaluative	Evaluates work or action	“Now, for the first time, we have a real problem.”
Organizational	Organizes or controls behavior	“Let’s go through all the triangles.”
Interrogative	Poses questions	“Look … what do you think this shape is?”
Responsive	Replies to questions	- “What about that one?” - “It is also too big.”
Repetitive	Repeats spoken language	- “Here they are probably.” - “Yeah, probably.” - “Probably.”
Agrees	Expresses agreement	“Yeah … it is the triangle.”
Disagrees	Expresses disagreement	“It cannot be.”
Dictation	Dictates text	“Write three, twenty-five, nine, twenty-one, and thirty-five.”
Reading aloud	Reads text aloud	“Twenty-two … thirty … six … okay.”
Affective	Expresses feelings and emotions	“I feel a bit ashamed … this is a crazy idea.”

Appendix E. Social activity categories (Source: Kumpulainen & Kaartinen, 2003)

Category	**Description**
Collaborative	Joint activity characterized by equal participation and shared meaning making
Tutoring	Student helping and assisting another student
Argumentative	Students are faced with social or cognitive conflicts that are resolved by rational argumentation and demonstration
Conflict	Students are faced with cognitive and social conflicts that are left unresolved
Domination	Student dominating the work, which leads to unequal participation in joint reasoning
Confusing	Characterized by the lack of shared understanding

Appendix F. Dissertation Instrument Definition Book

For Collaborative Interdependence Rating and Observation Scheme

Aspect of Collaboration process	**Rating scheme's dimensions**	**Definitions**
Interdependencies in Team Communication and Interaction	Collaboration Flow: a. Turn-taking	Collaboration flow refers to a coherent sequence of messages, communicating verbally and/or through actions, that build upon one another and thus enable the exchange, interpretation, and integration of knowledge and ideas in the collaborative problem solving process (Rummel, Deiglmayr, Spada, Kahrimanis, & Avouris, 2011)
	Sustaining mutual understanding	The maintenance of a joint focus and the joint work towards "common ground"
	Repairing (conflicts)	Collaborators use a series of actions (e.g., explanation, elaboration, suggestions, assertion, and justification) to reduce misunderstanding or miscommunication
	Joint Participation & Mutual Engagement	Respectful, collaboratively oriented social interactions and partners' equality in contributing to problem solving and decision-making (Kumpulainen & Kaartinen, 2010; Dillenbourg, 1999)
Interdependencies in Team Coordination and Management	Task Division & Management	Assessment of how well participants manage tasks together
	Time Management	Assessment of how participants cope with time constraints
	Technical Coordination	Assessment of how participants collaborate by using technology and how to solve technical issues together
Interdependencies in Team Collaborative Reasoning	Joint Information Pooling & (Knowledge Exchange)	Joint information pooling denotes eliciting information and giving appropriate explanations
	Reaching Consensus	Reaching consensus denotes the process of discussing and critically evaluating information in order to make a joint decision

Appendix G. Interdependence Rating and Observation Scheme (Initial Version)

Interdependence Rating / Observation Sheet

(Evaluating the Quality of *Collaborative Interdependence* in SameTime Meetings)

Team meeting date______________________ Meeting duration ________________________________

Team meeting participants____

Meeting moderator ____

Location of team participants: ____

Purpose of the meeting____

Technology and/or Tools used:____

WB Attachments ____

Foreshadowed Questions:

Overarching question: what are relationships between *interdependency* among team participants (reflected in interdependencies in collaborative communication, collaborative reasoning, and team coordination and management) and team *convergence* in collaboration?

1. How did participating students communicate and interact as a team (i.e., building up interdependencies in communication)?
2. How did participating students solve the problem interdependently as a team (i.e., establishing common understanding and reasoning together)?
3. How did participating students manage the team interdependently (i.e., collaboration in team management, task management, and technical coordination)?

Part 1.*Interdependencies* in Team Communication and Interaction

	Often	**Sometimes**	**Never or Not Observed**
Collaboration Flow: Turn-Taking *(Collaboration flow refers to a coherent sequence of messages, communicating verbally and/or through actions, that build upon one another and thus enable the exchange, interpretation, and integration of knowledge and ideas in the collaborative problem solving process)*			
1. Team participants were able to ensure *mutual attention*			
a. A participant checked his or her partners' availability before he or she started to talk			
b. Team participants handed over turns by explicitly asking a question or naming the next speaker			
2. Team members had smooth conversational transition turns (i.e., team's conversation was built upon each other)			
Collaboration Flow: Coordination of Language and Action			
3. Team members conveyed their conversation both verbally and through actions and/or tools			
a. Team members used actions or gestures to (help) his/her demonstration while verbalizing ideas and opinions			
b. Team members used tools to (help) his/her demonstration while verbalizing ideas and thoughts			
Complementary Notes: a. Based on your observation, what tools are (most) frequently used by the team? b. Describe one example that the team participants use tools to help demonstrate or explain his ideas:			
4. Team members were able to explain his/her actions to partners			

	Often	Sometimes	Never or Not Observed
5. The team had an effective division of labor: while one focused on implementing actions, the other concentrated on producing utterances to either explain or improve the action			
Complementary comments: Other observation findings:			
Sustaining Mutual Understanding *(including the maintenance of a joint focus and the joint work towards "common ground")*			
6. Team's conversation always focused on and contributed to the operation of team problem solving activities			
7. Team's establishment of *mutual understanding* of shared concepts, assumptions and expectations was actively sustained and/or enlarged during conversation			
a. Speakers (frequently) checked listeners' understanding			
b. Listeners gave positive evidence of his or her understanding by employing explicit feedback strategies, such as verbal acknowledgements or paraphrases			
c. Listeners asked questions or requested further elaboration when they did not understand speakers' explanation or demonstration			
d. Collaborators are able to elaborate or paraphrase partners' ideas			
8. Students were able to successfully interpret partners' action in his/her utterances			

	Often	Sometimes	Never or Not Observed
Complementary comments: Other observation findings:			
Repair (conflicts)			
9. Collaborators had attempts and/or actions to clarify his/her points of views and reduce conflicts and/or confusion			
10. Collaborators had attempts and/or actions to resolve misunderstanding in communication and/or interpretation of an idea			
11. Collaborators used different strategies (e.g., suggestions, assertion, elaboration, justifications) to get the partners coordinated			
12. Collaborators were able to take conflicts as team problems and solved collaboratively			
Complementary comments: Other observation findings:			
Joint Participation &Mutual Engagement *(Respectful, collaboratively oriented social interactions and partners' equal in contributing to problem solving and decision)*			
13. Team members had equal participation in contributing to problem solving and decision making			
Complementary comments: a. If you observe any dominance during the meeting conversation, please describe:			

	Often	Sometimes	Never or Not Observed
b. If you observe any tutoring (e.g., in content area, in technology use) during the meeting conversation, please describe: c. Other observation findings:			
14. Team participants showed collaboratively oriented social interactions (e.g., constructive handling of disagreements)			
15. Team participants maintained a high level of task orientation throughout their collaboration			

Part 2.*Interdependencies* in Team Coordination and Management

	Often	**Sometimes**	**Never or Not Observed**
Task Division & Management *(Assessment of how well participants manage task-subtasks dependencies)*			
16. Team participants discussed and developed plans of how to approach a task and negotiate the joint efforts			
a. Team participants considered the nature of the tasks, individual resources, and fields of expertise when they negotiated about task division			
b. Individual work phases were scheduled (so that collaborators can bring their individual domain knowledge to bear)			
c. Joint phases were scheduled (so that team participants could work together on more integrative aspects of the task and toward a coherent joint solution)			
17. Team scheduled a moderator for every SameTime meeting			
18. Team had a list of specific tasks that the meeting moderator should complete for every SameTime meeting			
19. The meeting moderator completed all required tasks			
Complementary comments: Other observation findings:			
Time Management *(Assessment of how participants cope with time constraints)*			
20. A working schedule/agenda was set up (e.g., due dates for each task, role of each team participant)			
21. Team had contingency plan(s) to cope with time constraints and/or to ensure a timely and orderly solution to the given problem			
Other observation findings:			

	Often	Sometimes	Never or Not Observed
Technical Coordination *(Assessment of how participants cope with technical issues together)*			
22. Team had certain rules for better technology use. For instance, checking team members' availability and video/audio quality at the beginning of the meeting before they start the working session			
23. Team participants helped each other when their partners' encountered technical confusion or difficulties			
24. The team coordinated in technology use: when one focused on implementing technology in producing design work or explain a concept, the other concentrate on explaining or illustrating the action			
Use one or two examples that you observed in the video to describe how team participants helped their partners cope with technical difficulties:			
Motivation– Individual Task Orientation (rate separately for each participant) *Literature (Meier, Spada, &Rummel, 2007) suggested that the collaboration process would reflect participants' individual motivation and their commitment to their collaborative work*			
25. Team participants focused their attention on the task and co-orientated their actions around it			
Mike-a. Participant focused attention on solution-relevant information			
Mike-b. Participant kept their environment free of distraction			
Mike-c. Participant nurtured positive expectations regarding the collaborative outcomes			
Complementary comments: Other observation findings:			

Part 3.*Interdependencies* in Team Collaborative Reasoning

	Often	Sometimes	Never or Not Observed
Joint Information Pooling *(denotes eliciting information and giving appropriate explanations)*			
26. Team participants externalized his or her own knowledge			
27. Team participants elicited/asked information from their partners			
28. Team participants provided explanations for their actions and/or ideas			
29. Team participants used tools to help explain their action and/or ideas			
30. Explanations from team participants were timely			
31. Explanations from team participants were given at an appropriate level of elaboration that the team members were able to understand			
Complementary comments: Other observation findings:			
Reaching Consensus *(denotes discussing and critically evaluating information in order to make a joint decision)*			
32. Team spent time on critically evaluating the given information/perspectives			
33. Team collected arguments for and against options at hand and critically discussed different perspectives			
34. Team composed specific criteria or establish certain rationale to evaluate the quality of their solution(s)			

	Often	Sometimes	Never or Not Observed
Complementary comments: Other observation findings:			

Appendix H. Interdependence Rating and Observation Scheme (Final Version)

Behavioral Interdependence Rating and Observation Scheme

Rating scale:
0 – not observed / applicable
1 – Sometimes
2 – Frequently

Part 1. Behavioral interdependence in Team Communication and Participation

Collaboration flow: Turn-taking
(Collaboration flow refers to a coherent sequence of messages)

1. Team participants were able to ensure mutual attention			
a. A participant checked his or her partners' availability and technology normalization at the beginning of a meeting	2	1	0
b. Team participants handed over turns by explicitly asking a question or naming the next speaker	2	1	0
2. Team participants had smooth conversational transition turns (i.e., conversation was built upon each other)	2	1	0

Joint participation
(Joint participation refers to partners' mutual contribution to problem-solving and decision-making and collaborators showed collaboratively-oriented social interactions)

3. Team participants had mutual participation	2	1	0
4. Team participants showed collaboratively oriented social interactions (e.g., handling disagreements as a team)	2	1	0
5. Team participants focused attention on solution-relevant information	2	1	0
6. Team participants kept their environment free of distraction	2	1	0

Part 2. Behavioral interdependence in Team Planning and Technology Use

Task management
(Assessment of how the team managed the team and coordinated with task division)

7. Team participants discussed and developed plans of how to approach a task and negotiate the joint efforts	2	1	0
8. Team participants considered the nature of the tasks, individual resources, and fields of expertise when they negotiated about task division	2	1	0
9. The team discussed about sharing regular routine tasks, which include taking meeting minutes, scheduling next ST meeting, saving WB notes, taking course surveys, and writing weekly progress reports	2	1	0

Temporal planning and management

(Assessment of how the team coped with time constraints)

10. A working schedule / agenda for the meeting was set up (e.g., tasks for the meeting, duration of each task)	2	1	0
11. Team participants checked the team's progress	2	1	0
12. Team participants checked each individual's progress	2	1	0
13. Team had contingency plan(s) to cope with time constraints and to ensure a timely and orderly solution to the given problem	2	1	0

Technological coordination

(Assessment of how the team used technology and coped with technical issues together)

14. Team used tools to help with communication and tasks	2	1	0
15. Team participants helped each other when their partners encountered technical confusion or difficulties	2	1	0

Part 3. Behavioral Interdependence in Team Collaborative Decision-making

Joint information communication & sustaining mutual understanding

(Denotes how the team shared information and made joint efforts towards the "common ground")

16. Team participants externalized his or her own knowledge	2	1	0
17. Listeners provided evidence of his or her understanding through explicit feedback, such as verbal acknowledgement or summarizing speakers' ideas	2	1	0
18. Listeners asked questions or required further elaboration when they did not understand speakers' explanation or demonstration	2	1	0
19. Team participants provided explanations for their actions and / or ideas	2	1	0
20. Explanations from team participants were timely	2	1	0
21. Explanations from team participants were given at an appropriate level of elaboration that the team members were able to understand	2	1	0

Repair (conflicts)

(Assessment of how the team coped with conflicts and disagreements as a team)

22. Collaborators had attempts and/or actions to clarify his/her points of views and reduce conflicts and/or confusion	2	1	0
23. Collaborators were able to take conflicts as team problems and solved the conflicts collaboratively	2	1	0

Reaching decisions

(Denotes how the team made a joint decision)

24. Team spent time on critically evaluating the given information	2	1	0
25. Team were accountable for multiple solutions and collected arguments for and against options at hand	2	1	0
26. Team discussed about criteria to decide and support their final solution	2	1	0

Appendix I. Collaboration Conversation Transcript Analysis Categories (Part 1)

Part 1: Communicative Functions

Communicative Function of Dialogue Threads	**Description & Definitions**	**Examples**
Informative	Provides information or action	"Oh, I'm done" "Hey my voice feed keeps breaking up"
Argumentative	Justifies information, thoughts, or actions	"I mean regardless whether the guns work or not I really don't think they are going to be much help other than for people trying to maybe bully each other around and you know, brandish them. I think they would just cause more trouble than help, I can't make use of them, I still agree they go towards the bottom but I think maybe they would work."
Reasoning	Provides reason in language	"Yeh I think box of matches definitely last *because* even though you are not going to be floating on water or life raft, maybe you could figure out something to do with it, but the matches are just worthless." "I can't really see the purpose *so* I'll put the box of matches at 15"
Explanative / Elaborative	Explain or elaborate one's ideas, work, or action	"Well if we assume it works I think it's a good idea to keep it but if we are going to take the assumption that it doesn't work, then yeh I guess we can dump it."
Suggestive	Suggests new ideas and/or actions	"Okay real quick, can you up on the white board, just put the numbers down next to the equipment of what we have concrete right now so we can take a look at that if you don't mind."
Confirmative	Strengthens ideas, actions, or opinions	"I'm having that same problem."
Summative / Conclusive	Summarize one's or the team's work or action	"Alright so uh, we got so magnetic compass and first aid kit."

Communicative Function of Dialogue Threads	**Description & Definitions**	**Examples**
Evaluative	Judges or determines the worth, value, or significance of one's work or action	"Yeh that's a great/good idea" "That's a pretty cool idea. I don't know if I'd have enough gas to blow my oxygen, blow my oxygen supply hoping to propel myself but it's a pretty cool idea"
Organizational	Organizes or manages team behaviors, actions, or structure/scheduling	"Yeh we have to rank everything, we kind of have to do it. I guess there's like 15 items so like 1-15." "Okay we'll crank this out quick."
Interrogative	Asks questions	"Alright how you guys making out? I'm done ranking mine." "Does anybody think that they are not necessary?"
Responsive	Responds questions	"I have no idea, hold on let me just try mine real quick here. "
Repetitive	Repeats spoken language of the person himself's or another team member's	BK said "Well if we assume it works I think it's a good idea to keep it but if we are going to take the assumption that it doesn't work, then yeh I guess we can dump it." BZ then repeated "Yeh if we assume that it works I think it's a really important thing to have but like I say, if we decide what we want to assume."
Agrees	Expresses agreement on ideas, opinions, and/or actions	"Yeh I put my vote on the food and rope too for those last two numbers that we need." "Yep I like that. That works for me."

Communicative Function of Dialogue Threads	**Description & Definitions**	**Examples**
		"I'll agree with that."
Disagrees	Expresses disagreement	
Dictation	Dictates text	
Reading aloud	Reads (text) aloud	"Then the two twenty five, I'm sorry fifty kilo tanks of oxygen."
Affective	Expresses feelings and emotions	"Yeh good job you guys, see you guys later." "You guys made it painless." "Alright cool, so uh here's our wonderfully written ranking"

Appendix J: Collaboration Conversation Transcript Analysis Categories (Part 2)

Part 2: Types of Team Decisions

Types of Team Decisions	
At the basic level: to ensure the fluency of a conversation	
1. Working strategies	1.1 Working format (e.g., collaborative working session or individual working session)
	1.2 Collaborating strategies (e.g., how to debate as a team and what presentation tool the team should use)
	1.3 Working procedures (e.g., confirming that all members completed the task)
2. Technology-related issues	2.1 Sharing and building up common understanding on technical issues/difficulties
	2.2 Sharing knowledge and/or building up common understanding regarding specific technology tool
	2.3 Selection and use of particular technology tools
3. Team management	3.1 Task division
	3.2 Assigning roles and responsibilities
	3.3 Scheduling
At the deep level: to ensure the operation of the problem-solving	
4. Content-related problem solving	4.1 Sharing information and knowledge and building up common understanding on assumptions or rationales
	4.2 Sharing knowledge and thoughts on alternative solutions
	4.3 Sharing knowledge and building up common understanding on (key) concepts and terms

Appendix K: Collaboration Conversation Transcript Analysis Categories (Part 3)

Part 3. Micro-analytic Map

The following micro-analytic map is used for the conversation analysis. Every conversation piece were analyzed based on its communicative function and how it contributes to the formation of a specific decision.

(Analysis of Constructing Shared Understanding towards decisions)

Micro-analytic Map

Participants	**Conversation Transcript**	**Communicative Function**	**Type of Decisions**
AA	…	Suggestive	Decisions on team management

Appendix L: An example of using the original Micro-analytic Map (scanned copy)

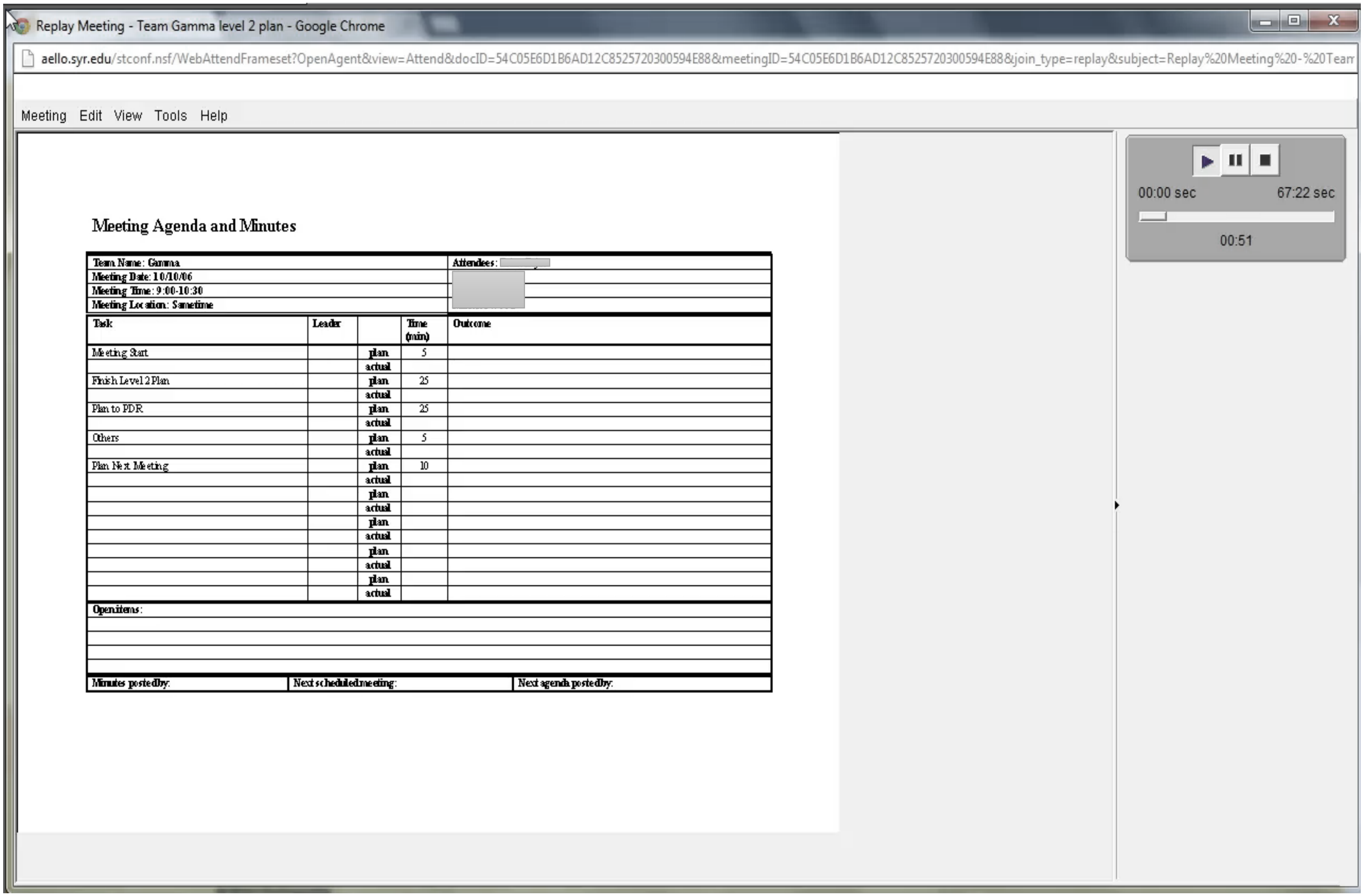
Source: Kumpulainen & Kaartinen (2003)

TABLE 7. The Nature of Social Interaction in Case Dyad 1

Session: 1.1.2 Mathematics
Pupils: Sami and Teemu
Working time: 9:09–9:23

Time	Participation No.	Participation Student	Transcribed peer interaction	Communicative functions	Social activity	Contextual notes
9:18	125	Teemu	"Bottom…. How come?"	Argumentative Question	Collaborative	
9:19	126	Sami	"No … but that's the bottom … that's that sort of a triangle and the lid is that sort of a triangle … they are connected … it shows there how they are connected."	Answering by demonstration	Collaborative Tutoring	
	127	Teemu	"No … look … this is…."	Argumentative		
	128	Sami	"Yeah … it's connected."	Argumentative		
	129	Teemu	"Wait."	Organizing		
	130	Sami	"That could be created by side triangles in a way."	Reasoning		
	131	Teemu	"A triangle comes here … a triangle comes here … a triangle comes here and here comes a rectangle."	Reasoning by demonstration		Outlining the geometrical object

Appendix M. Screen-captured meeting agenda for Team Gamma' selected meetings on Oct. 10 and Oct. 27



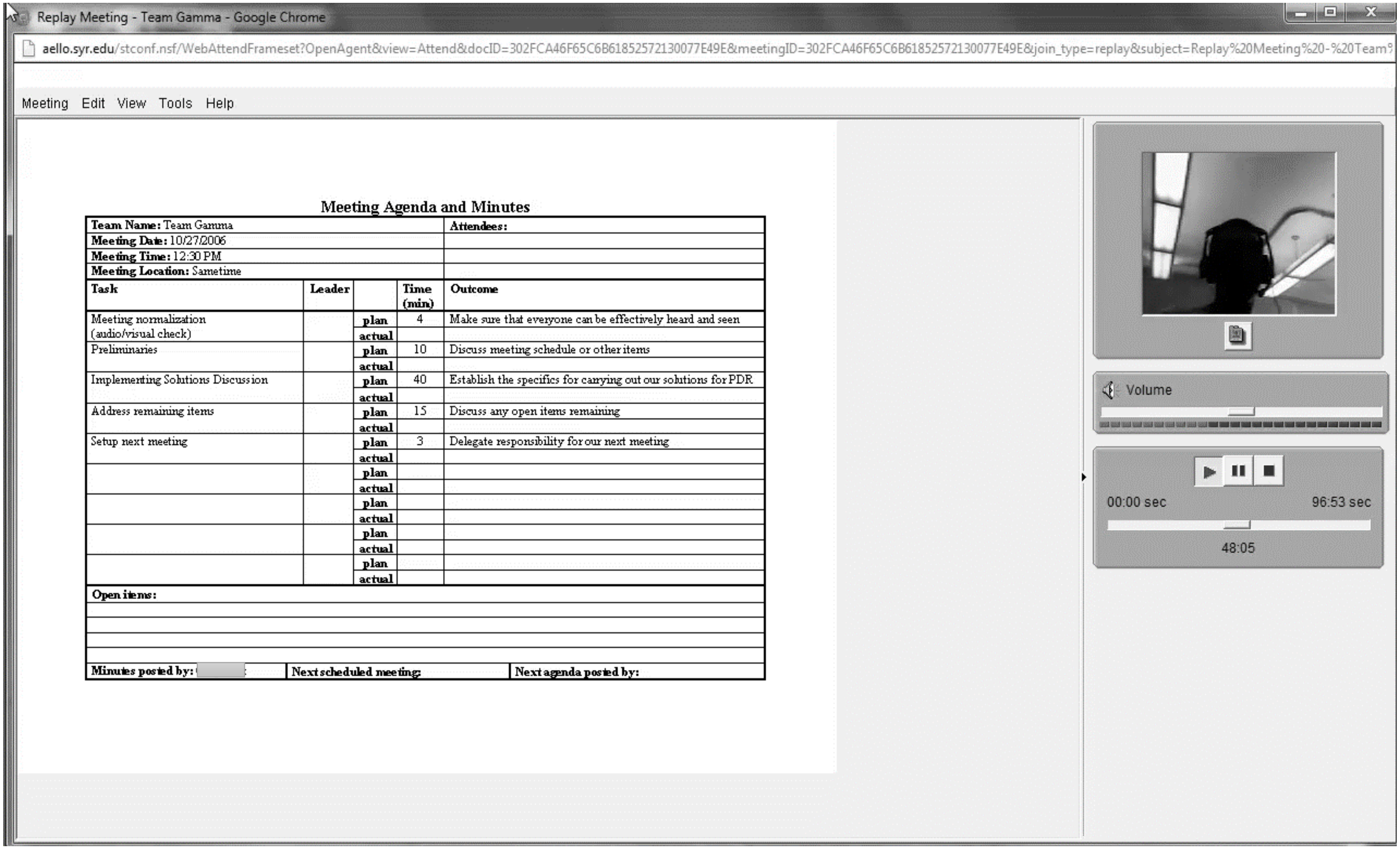
Meeting Agenda and Minutes

Team Name: Gamma	Attendees:
Meeting Date: 10/10/06	
Meeting Time: 9:00-10:30	
Meeting Location: Sametime	

Task	Leader		Time (min)	Outcome
Meeting Start		plan	5	
		actual		
Finish Level 2 Plan		plan	25	
		actual		
Plan to PDR		plan	25	
		actual		
Others		plan	5	
		actual		
Plan Next Meeting		plan	10	
		actual		
		plan		
		actual		
		plan		
		actual		
		plan		
		actual		
		plan		
		actual		

Open items:

Minutes posted by:	Next scheduled meeting:	Next agenda posted by:



Meeting Agenda and Minutes

Team Name: Team Gamma	**Attendees:**
Meeting Date: 10/27/2006	
Meeting Time: 12:30 PM	
Meeting Location: Sametime	

Task	Leader		Time (min)	Outcome
Meeting normalization (audio/visual check)		**plan**	4	Make sure that everyone can be effectively heard and seen
		actual		
Preliminaries		**plan**	10	Discuss meeting schedule or other items
		actual		
Implementing Solutions Discussion		**plan**	40	Establish the specifics for carrying out our solutions for PDR
		actual		
Address remaining items		**plan**	15	Discuss any open items remaining
		actual		
Setup next meeting		**plan**	3	Delegate responsibility for our next meeting
		actual		
		plan		
		actual		
		plan		
		actual		
		plan		
		actual		
		plan		
		actual		

Open items:

Minutes posted by:	**Next scheduled meeting:**	**Next agenda posted by:**

- Image of student face was blocked

Appendix N. Task description of Lab 1 task

Collaborative Engineering Design **Lab 1 Space Survival Exercise**

Purpose of Exercise

Set up a ST Meeting. **Conduct an on-line team meeting**. Go through **meeting normalizations** (clear video images, uniform audio levels, appropriate microphone sensitivities, common pc screen resolutions), choose a **speaking protocol** (free talk, talk & mute, request microphone), utilize **confirmations** (raise hands or chat). **Have some fun with your new teammates!**

Overall of Exercise

1. Go through meeting normalizations
2. Read the assignment, which requires your team to work together to survive a crash landing on the moon. This has two parts:
    a. Individually decide what you would do (10 minutes)
    b. Share your ideas with the team and then agree on a common approach
3. Document your results and transmit them electronically to the instructors for review
4. Save and end the meeting
5. Take a short on-line survey

Meeting Normalization

1. Upon entering the meeting, make sure that you can see "chat" near the bottom of the SameTime window. Increase the space for this if needed.
2. Type into chat "I'm here" and whether you can see and hear whoever is speaking.
3. Your microphone sensitivity, microphone volume, and speaker volume should already be set from your "Test Audio/Video" process prior to entering the meeting. If you did not do this, exit the meeting and do so (unless you are the moderator, in which case you cannot).
4. Take turns talking. When you are the one talking, adjust your camera (if needed) to provide to clear view of your face.
5. When someone else is speaking, use chat to tell them to adjust their microphone volume up or down.
6. Everyone should be able to adjust their speaker and microphone volumes so that all participants are head at an equal volume that is comfortable to hear.
7. When complete, use confirmations (raise hands or chat) to determine if you all are satisfied with the audio and video.
8. Decide on the speaking protocol that you will use for this assignment (free talk, talk & mute, or request microphone)
9. Clear any hands that remain raised
10. Proceed to the next whiteboard screen and begin!

Step 1. Scenario and Individual Rankings

You and your team are members of a moon expedition that has had to make an emergency landing 250 miles from an intended rendezvous site with your return orbiter ship. During your landing, critical communication and life support equipment was damaged beyond repair. The orbiter ship does not have the capability to perform an extensive search for you. You have some limited supplies and equipment remaining onboard your exploration craft. Since your survival depends upon reuniting with the orbiter ship, you must travel over the moon's surface to the designated rendezvous site or close enough for visual contact. Of the equipment available, you must select those items that are most important for your team's survival. Your team must stick together. All of the items in the equipment list below are undamaged and in good working order.

Available Equipment

- Box of matches
- Food concentrate
- 20 meters of nylon rope
- Parachute silk
- Portable heating unit
- Two .45 caliber pistols
- One case dehydrated milk
- Two 50 kg tanks of oxygen
- Stellar map (of the moon's constellations)
- Lift raft
- Magnetic compass
- 25 liters of water
- Signal flares
- First aid kit w/hypodermic needle
- Solar-powered FM receiver/transmitter

To Do:

1. Individually go to (in a new browser window type in the URL): http://okyale.syr.edu/aide/spacesurvivalranking.doc
2. On your own, take 10 minutes to rank-order the items (1 is most important, 15 is least important). To do this, fill in only one column of the four that are under the "Individual Ranking" heading.
3. Raise your hand when you are finished
4. When everyone is finished, go to the next whiteboard

Step 2. Consensus Building and Transmittal of Results

1. In the form below, each team member should write their name into an empty heading square. Then, share your individual rankings with your teammate by recording them in that column
2. Choose a member as a recorder, and have this member fill in the names and rankings of all team members on their ranking form (i.e., into the Word document on their PC).
3. As a team, compare and discuss the individual rankings, agree upon a single team ranking, and fill this in. Have the recorder add this to the combined ranking form.
4. Write a short rationale for your top 5 choices (on the recorder's ranking form, beneath the table). Make sure that you all agree with what is written!
5. Have the recorder save and post the rankings (all in individual members plus the team's ranking) to your team's dropbox.
6. Go to the next whiteboard screen.

Equipment Ranking Form

	Individual Ranking				
	1	**2**	**3**	**4**	**Team Ranking**
Box of Matches					
Food concentrate					
20 meters of nylon rope					
Portable heating unit					
Parachute silk					
Two .45 caliber pistols					
One case dehydrated milk					
Two 50 kg tanks of oxygen					
Stellar map (of the moon's constellations)					
Lift raft					
Magnetic compass					
25 liters of water					
Signal flares					
First aid kit w/hypodermic needle					
Solar-powered FM receiver/transmitter					

Step 3. Leave/End the Meeting, Take Short Survey, Look at Expert Rankings

1. Go to the AIDE (QuickPlace) in a different browser window. Click on Survey/SpaceSurvival. In the upper right corner, click on "New Space Survival Survey". Take this survey – when finished, click on "Submit". THIS IS REQUIRED TO RECEIVE CREDIT FOR THIS EXERCISE.
2. At the end of the survey, there will be a URL to access expert rankings and their rationale. Take a look and see how your team' ranking compare!!
3. Expert for the meeting moderator, you may now leave this SameTime meeting at any time (use Meeting/Leave Meeting). Don't close this browser window until you have successfully exited the meeting!
4. The moderator (generally the person that scheduled the meeting) should *save & end the meeting* (Meeting/Save/whiteboard & chat; Meeting/End meeting). THIS IS REQUIRED FOR FULL CREDIT. Don't close this window until you have successfully completed this step!

Appendix O. Meeting Agenda of Team Alpha's Selected Project Planning Meeting

Team Alpha Meeting Agenda **10/5/06**

Data: Thursday, 10/5/06
Time: 1:30 – 2:30 pm *(that means get prepped at 1:20 pm)
Location: SameTime

Pre-meeting Responsibilities:
Justin: Determine free time or have your schedule handy
Louis: Determine free time or have your schedule handy + (be on time)
Greg: Determine free time or have your schedule handy
Adil: Determine free time or have your schedule handy + (be on time)

Subjects to be covered:

- Free-time Scheduled:
  - When is a good time to have meetings in the future?
  - How should we organize meetings:
    - weekly on a set day
    - differently each week

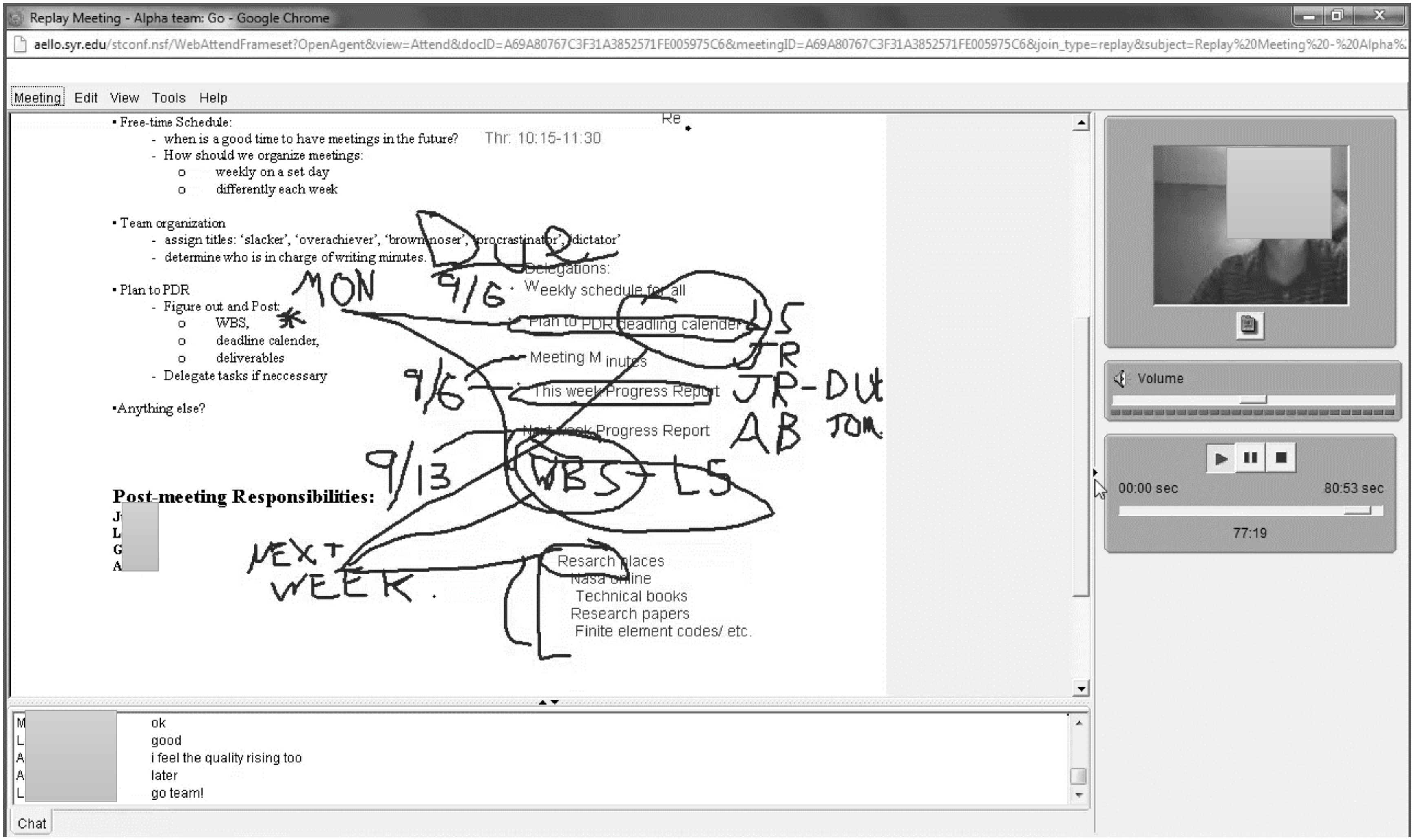
- Team organization
  - Assign titles: 'slacker', 'overachiever', 'brown-noser', 'procrastinator', 'dictator'
  - Determine how is in charge of writing minutes.

- Plan to PDR
  - Figure out and Post
    - WBS,
    - Deadline calendar,
    - deliverables
  - Delegate tasks if necessary

- Anything else?

Post-meeting Responsibilities:
Justin:
Louis:
Greg:
Adil:

Appendix P. Team Alpha Project Planning Meeting Screen Capture of the Meeting Agenda Notes



- Image of student face shown in the meeting video and students' full names were blocked

Appendix Q. Team Gamma working document in its selected project planning meeting

Level 1.5 plan

Team Gamma
10/05/2006

I. <u>Important Dates</u>

- **10/17**
  We have to have a plan to PDR finished and put it onto two slides. During lecture on this day we will spend 35 minutes with a professor reviewing it. *Must annotate each slide.*

- **11/06 – 12 Noon**
  Our PDR presentation is due and needs to be no longer than 20 slides. It needs to be posted in our teams drop box. *Each slide needs to be annotated.*

- **11/07**
  During lecture we will orally present our PDR. Everyone's attendance is required.

II. <u>Level 1.5 Plan</u>

1. Identify the problem

Decide on the general problem which needs to be addressed for the project.

1. Study Handout (home>full class>assignments>08-29-06>DP Description Fall 06 PDF)
2. Identify general needs

2. Define the Problem

Very specifically define the objective of the project

1. Research into previous, related work (e.g., how to attach panels to CEV)
2. Generate specifications (e.g., FOM, definition of safety)

3. Brainstorming

Generate a good list of ideas and make sure to fully consider anything that is mentioned. In this stage we generate ideas we do not, however start making decision on which ideas to keep or throw out.

4. Evaluate Potential Solutions

At this stage we fine tune the mess we made from brainstorming.

1. Organize Ideas
2. Combine Ideas
3. Will they meet the general requirements?
4. Use a Morph chart

5. Implement Solutions

Actually compute potential solutions which were decided on.

1. Computer / Analyze solutions
    a. Using FEM
    b. Closed form analysis
2. Compare sets of solutions (FEM vs. closed) to gauge accuracy
    a. Solutions should be close
    b. Decide on which solution to go with
3. Pool best ideas into design
4. Come up with new / better designs and compute solutions for those (this will be a very iterative part of the project)

6. Evaluate the Designs

Consider the designs we have.

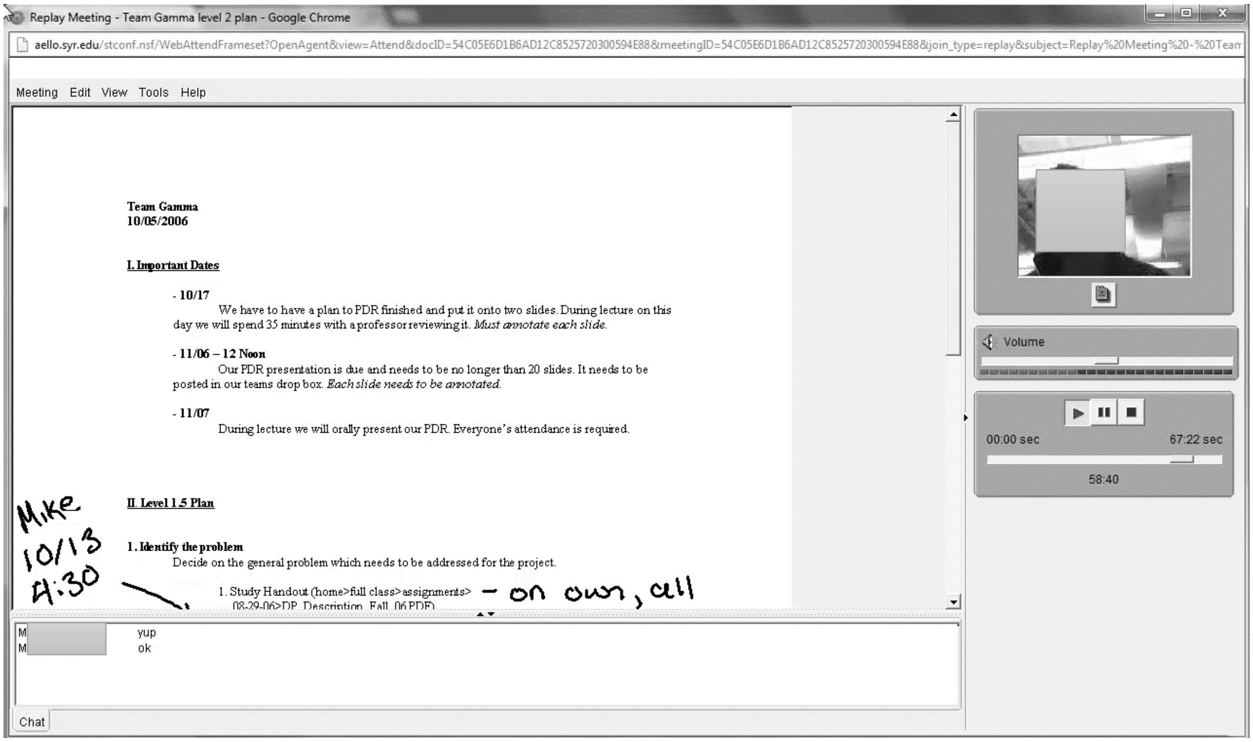
1. Do they meet the general requirements set forth for the project?
2. How well do they fit with our *previously defined* FOM?
3. Iterations…Can we go back and make some of our designs better?

7. Final Product

For the 90 degree "hot side" orientation we have a suitable configuration for a CEV panel which is structurally sound, can be readily attached to the CEV, and can withstand all of the temperature, pressure, and mechanical loads it will experience.

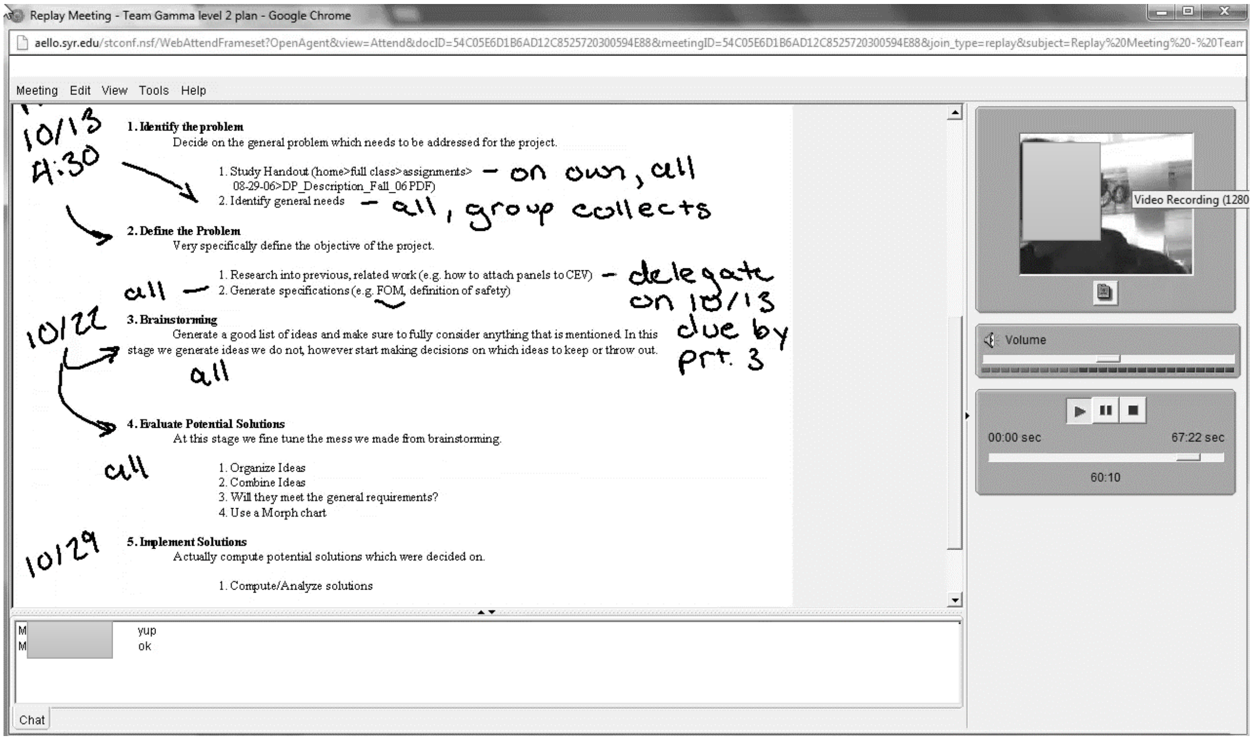
Appendix R. Screen-captures of team Gamma's working notes on upgrading its Level 1.5 plan to Level 2.0 plan in the selected project planning meeting

Screen-capture 1

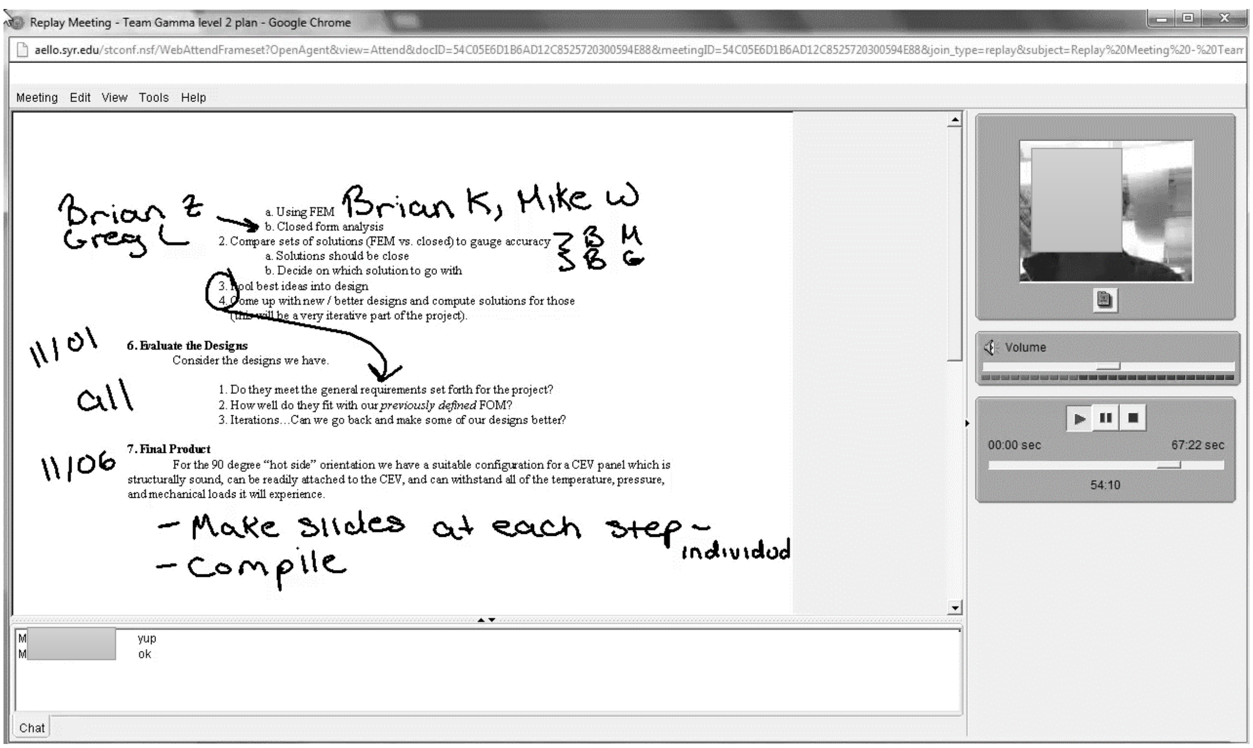


- Image of student's face shown in the meeting video was blocked

Screen-capture 2

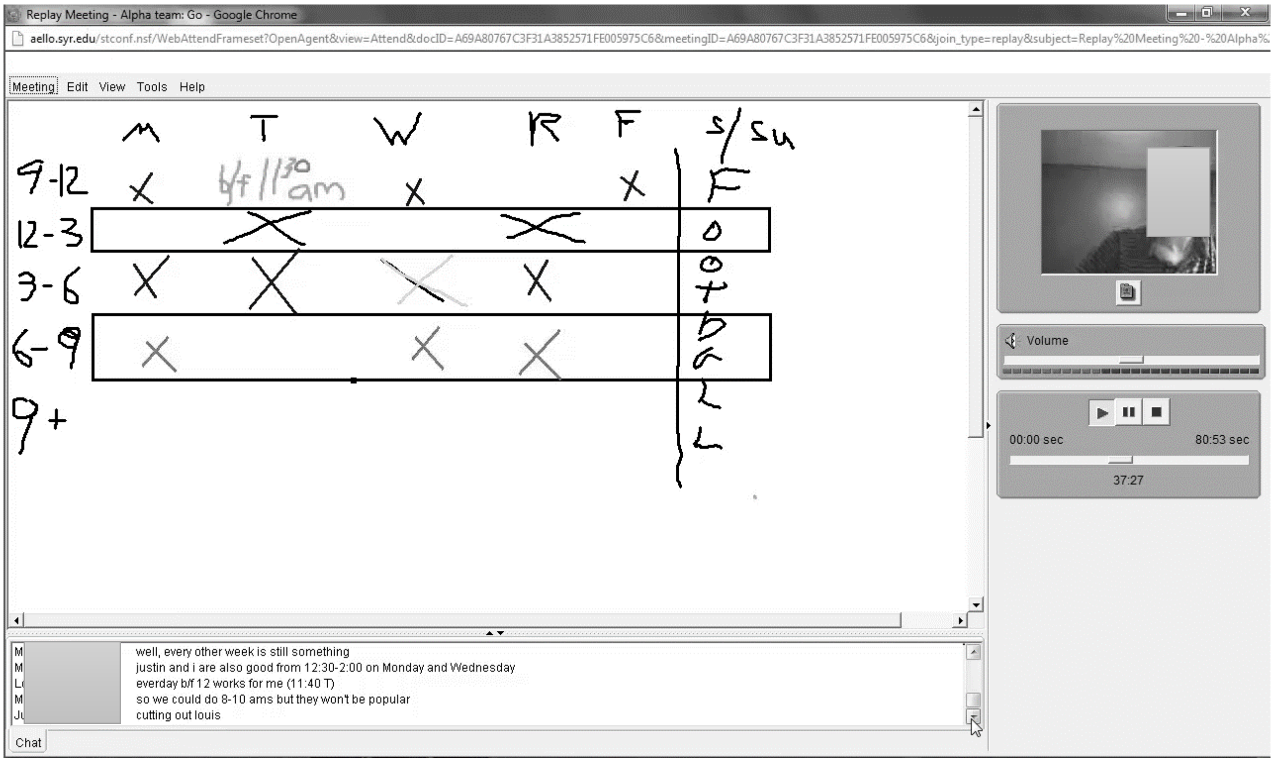


Screen-capture 3



- Image of student face shown in the meeting video and students' full names were blocked

Appendix S. Screen-capture of team Alpha's scheduling chart in the selected project planning meeting



- Image of student face shown in the meeting video and students' full names were blocked

Appendix T. Student DST and university distribution

Discipline Specific Track Rosters

Collaborative Engineering Design

Aerospace Structures

UNIVERSITY A
GL (Team Gamma)
JR (Team Alpha)

UNIVERSITY B
LS (Team Alpha)
BZ (Team Gamma)

Finite Element Analysis

UNIVERSITY A
GA (Team Alpha)
AF (Team Alpha)
MW (Team Gamma)

UNIVERSITY B
AB (Team Alpha)
BK (Team Gamma)

Appendix U. Key concepts

Key Concepts	**Definitions**
Collaboration flow	a coherent sequence of messages, both verbally and conveyed through actions, which build upon one another and thus enable the exchange and integration of knowledge and ideas in the collaborative problem solving process" (Meier et al. (2007, p. 377).
Interdependence	"the quality or condition of being mutually reliant on each other" (dictionary.com)
Task interdependence	The term is also named as task structural interdependence, is associated with how the task is designed. Task interdependence is consist of four components: (1) how the work is defined; (2) how instructions about the work process are given; (3) whether the technology support interdependent work approaches; and (4) how resources, including skills, information, knowledge, and materials, are distributed among team members.
Behavioral interdependence	the extent to which collaborators participate in task task-focused interaction. Such collective approaches may evolve into a patterned, consensual behavior of individual collaborators as a team.

Key Concepts	**Definitions**
Collaboration	is composed of a sequence of coordinated, synchronous, interdependent, and reciprocal activities in communication, cognition, and team dynamics. During collaboration, participants continuously construct and maintain a shared understanding of a problem, and collectively process and solve the problem toward a joint outcome. Collaboration requires group members' mutual participation in a coordinated effort to tackle the problem together. In collaboration, students share high level of mutuality and interdependence.
Cooperation	is carried through by dividing tasks among participants and is an activity where each person accounts for a portion of the problem solving. In cooperation, students share low level of mutuality and interdependence.
Planning	is a process of making a procedure or means for attaining a goal
Repair	is the strategy by which discourse participants tackle problems or discrepancies in collaborative communication. The term is also named as self-correction and refers to collaborators' attempts and actions to clarify his/her points of views, reduce

Key Concepts	Definitions
	conflicts, and resolve misunderstanding in communication and interpretation of an idea.
Project collaboration team	Project teams were usually gathered for tackling a complex (short-term) project, which requires expertise and skills from multiple disciplines. In an organization, individuals in project teams usually come from different divisions or units. Therefore people working in project teams are subject to varying temporal constraints from deadlines required by the project and the responsibilities from their own units or organizations. Project teams possess "complete autonomy to decide how to accomplish the task" (Janicik & Bartel, 2003, p. 125) as self-managing teams.
Instrumental case study	In an instrumental case study, the case serves to help understand phenomena within it. Instrumental case study researchers use a particular case as the instrument to serve the need for general understanding to the research question rather than to understand the case.

Appendix V. Peer-self Assessment Survey

#	Question	Scale
1	Did the team member make it to meetings? Was the member on time and prepared for meetings? Did the team member complete their share of the agreed upon work?	1-7
2	How effective was the team member? How valuable was their contribution to the overall team goals and progress?	1-7
3	Did the team member contribute by attitude and action to team morale and group confidence?	1-7
4	You have $12,000 to distribute to your teammates (not including yourself) for work well done. For each teammate, enter the amount that you would give to them (total must equal $12000).	0-12000
5	If there are any specific issues or problems with your team or a particular team member that the faculty should be aware of, you may provide written comments below. Comments will be seen by the faculty only.	Text
6	Did you attend meetings? Were you on time and prepared? Did you complete your share of the agreed upon work?	1-7
7	How effective were you? How valuable was your contribution to the overall team goals and progress?	1-7
8	How satisfied are my teammates with my work contributions?	1-7
9	If you had to give yourself a grade (A-F) for your work on the project to-date, what would it be.	F-A
10	Provide justification for your overall grade above. As part of your response, indicate your two most significant contributions to the project (e.g. the amount of work that you did, the quality of this work, the coordination of your efforts with other to produce integrated results, or other considerations).	Text

References

Allen, B. C., Sargent, L. D., & Bradley, L. M. (2003). Differential effects of task and reward interdependence on perceived helping behavior, effort, and group performance. *Small group research, 34*(6), 716-740. http://dx.doi.org/10.1177/1046496403257615

Alper, S., Tjosvold, D., & Law, K. S. (1998). Interdependence and controversy in group decision making: Antecedents to effective self-managing teams. *Organizational Behavior and Human Decision Processes, 74*(1), 33-52. http://dx.doi.org/10.1006/obhd.1998.2748

Aube, C. & Rousseau, V. (2005). Team goal commitment and team effectiveness: The role of task interdependence and supportive behaviors. *Group Dynamics: Theory, Research, and Practice, 9*(3), 189-204.

Baker, M. J. (1994). A model for negotiation in teaching-learning dialogues. *Journal of Artificial Intelligence in Education*, *5*(2), 199-254.

Baxer, P. & Jack, S. (2008). Qualitative case study methodology: Study design and implementation for novice researchers. *The Qualitative Report*, *13* (4), 544-559.

Blader, S. L., & Tyler, T. R. (2009). Testing and extending the group engagement model: Linkages between social identity, procedural justice, economic outcomes, and extraole behavior. *Journal of Applied Psychology*, *94*(2), 445-464.

Bonito, J. A. (2002). The analysis of participation in small groups: Methodological and conceptual issues related to interdependence. *Small Group Research*, *33,* 412-438.

Bonner, S. E., Hastie, R., Sprinkle G. B., & Young, S. M. (2000). A review of the effects of financial incentives on performance in laboratory tasks: Implications for management accounting. *Journal of Management Accounting Research, 12*, 19-64.

Bower, M. (2008). Affordance analysis: Matching learning tasks with learning technologies. *Educational Media International, 45*(1), 3-15. doi: 10.1080/09523980701847115.

Brownlee, A. L. & Motowidlo, S. J. (2011). Effects of accountability to group members and outcome interdependence on task behavior and interpersonal contextual behavior. *Journal of Organizational Psychology, 11*(1), 24-35.

Cakir, M. P., Zemel, A., & Stahl, G. (2009). The joint organization of interaction within a multimodal CSCL medium. *Computer-supported collaborative learning, 4*, 115-149.

Caruso, H. M. & Woolley, A. W. (2008). Harnessing the power of emergent interdependence to promote diverse team collaboration, in Katherine W. Phillips (ed.) *Diversity and Groups: Research on Managing Groups and Teams, 11*, Emerald Group Publishing Limited, pp.245-266

Chan, T. W. (1989). *Learning Companion System*. Ph.D. Thesis, Department of Computer Science, University of Illinois at Urbana-Champaign.

Chan, R. Y-Y., Huang, J., Hui, D., Li, S., & Yu, P. (2013). Gender differences in collaborative learning over online social networks: Epistemological beliefs and behaviors. *Knowledge Management & E-Learning, 5*(3), 234-250.

Chiu, C. H. (2002). The effects of collaborative teamwork on secondary science. *Journal of Computer Assisted Learning, 18*, 262-271.

Cho, H., Gay, G., Davidson, B. & Ingraffea, A. (2005). Social networks, communication styles, and learning performance in a CSCL community. *Computer and Education, 49*, 309-329.

Countright, S. H., Thurgood, G. R., Stewart, G. L., & Pierotti, A. J. (2015). Structural interdependence in teams: An integrative framework and meta-analysis. *Journal of Applied Psychology, 100*(6), 1825-1846.

Damon, W. (1984). Peer education: The untapped potential. *Journal of Applied Developmental Psychology*, *5*(4), 331-343.

De Dreu, C. K. W. (2007). Cooperative outcome interdependence, task reflexivity, and team effectiveness: A motivated information processing perspective. *Journal of Applied Psychology*, *92*, 628-638. http://dx.doi.org/10.1037/0021-9010.92.3.628

De Dreu, C. K. W., & Van Vianen, A. E. (2001). Managing relationship conflict and the effectiveness of organizational teams. *Journal of Organizational Behavior*, *22*, 309-328. http://doi.org/cnj

Deutsch, M. (1962). Cooperation and trust: Some theoretical notes. In M. R. Jones (Ed.), *Nebraska symposium on motivation* (pp. 275-319). Lincoln: University of Nebraska Press.

Dillenbourg P. (1999). What do you mean by collaborative learning? In P. Dillenbourg (Ed) *Collaborative-learning: Cognitive and Computational Approaches* (pp.1-19). Oxford, UK: Elsevier.

Dillenbourg, P., Baker, M., Blaye, A. & O'Mally, C. (1996). The evolution of research on collaborative learning. In E. Spada & P. Reiman (Eds) *Learning in Humans and Machine: Towards an interdisciplinary learning science*. (pp. 189-211). Oxford: Elsevier.

Eaves, D. (2007). *Wiki's and open source: Collaborative or cooperative?* Retrieved from http://eaves.ca/2007/02/05/wikis-and-open-source-collaborative-or-cooperative/ on July 3, 2013.

Fan, E. T. & Gruenfeld, D. H. (1998). When needs outweigh desires: The effects of resource interdependence and reward interdependence on group problem solving. *Basic and Applied Social Psychology, 20*(1), 45-56.

Gable, R. A., Quinn, M. M., Rutherford, R. B., Howell, K. W., & Hoffman, C. C. (2000). *Addressing Student Problem Behavior: Part III: Creating Positive Behavioral Intervention Plans and Supports*. Washington: American Institutes for Research. Retrived from http://cecp.air.org/fba/problembehavior3/part3.pdf on January 15, 2017.

Geer, R., & Barnes, A. (2006). Media stickiness and cognitive imprinting: Inertia and creativity in cooperative work & learning with ICTs. In D. Kumar & J. Turner (Eds.), *Proceedings of the World Computer Congress*. Santiago, August. pp. 55-64.

Geer, R., & Barnes, A. (2007). Beyond media stickiness and cognitive imprinting: Rethinking creativity in cooperative work & learning with ICTs. *Educational Information Technology, 12*, 123-136. doi: 10.1007/s10639-007-9036-6.

Gersick, C. J. (1988). Time and transition in work teams: Towards a new model of group development. *Academy of Management Journal, 31*, 9-41.

Gersick, C. J., & Hackman, J. R. (1990). Habitual routines in task-performing groups. *Organizational Behavior and Human Decision Processes, 47*, 65-97.

Gonzales, R. A. (2010). *Health care team effectiveness: The relationship between team task interdependence and group emotional competence*. Retrieved from http://pqdtopen.proquest.com/doc/853643754.html?FMT=AI on Nov. 15, 2015.

Gundlach, M., Zivnuska, S., & Stoner, J. (2006). Understanding the relationship between individualism-collectivism and team performance through an integration of social identity theory and the social relations model. *Human Relations, 59*(12), 1603-1632. doi: 10.1177/0018726706073193.

Hackman, J. R. (1969). Toward understanding the role of tasks in behavioral research. *Acta Psychologica, 31*(2), 97-128.

Hackman, J. R. & Wageman, R. (2005). When and how team leaders matter. *Research in Organizational Behavior, 26*, 37-74. doi: 10.1016/S0191-3085(04)26002-6.

Hansen, D., Shneiderman, B., & Smith, M. A. (2011). *Analyzing Social Media Networks with NodeXL: Insights from a Connected World.* Burlington, MA: Elsevier.

Hinsz, V. B., Tindale, R. S., & Vollrath, D. A. (1997). The emerging conceptualization of groups as information processors. *Psychological Bulletin, 121*(1), 43-64.

Huysman, M., Steinfield, C., Jang, C.Y., David, K., Huis in 'T Veld, M., Poot, J., & Mulder, I. (2003). Virtual teams and the appropriation of communication technology: Exploring the concept of media stickiness. *Computer Supported Cooperative Work, 12*, 411-436.

Janicik, G. A. & Bartel, C. A. (2003). Talking about time: Effects of temporal planning and time awareness norms on group coordination and performance. *Group Dynamics: Theory, Research, and Practice. 7(2)*, 122-134.

Jeong, H. & Hmelo-Silver, C. E. (2016). Seven affordances of computer-supported collaborative learning: How to support collaborative learning? How can technologies help? *Education Psychologist, 51*(2), 247-265. doi: 10.1080/00461520.2016.1158654.

Johnson, D. W. & Johnson, R. T. (1989). *Cooperation and Competition: Theory and Research.* Interaction Book Company, Edina, MN.

Johnson, D. W. & Johnson, R. T. (2005). New developments in social interdependence theory. *Genetic, Social, and General Psychology Monographs, 131(4)*, 285-358.

Johnson, D. W. & Johnson, R. T. (2009). An educational psychology success story: Social interdependence theory and cooperative learning. *Educational Researcher, 38*(5), 365-379.

Johnson, D. W., Johnson, R. T., & Tjosvold, D. (2006). Constructive controversy: The value of intellectual opposition. In D. Morton, C. T. Peter, & M. C. Eric (Eds.) *The Handbook of Conflict Resolution: Theory and Practice*. (pp. 69-91). San Francisco, US: Jossey-Bass.

Jonassen, D. H. (2000). Toward a design theory of problem solving. *Educational Technology Research and Development, 48*(4), 63-85.

Jonassen, D. H., Strobel, J., & Lee, C. B. (2006). Everyday problem solving in engineering: Lessons for engineering educators. *Journal of Engineering Education, 95*(2), 1-14.

Kapur, M., Voiklis, J., & Kinzer, C. (2011). A complexity-grounded model for the emergence of convergence in CSCL groups. In S. Puntambekar, G.Erkens, & C. Hmelo-Silver (Eds.), *Analyzing interactions in CSCL: Methods, approaches and issues* (pp. 83-106). New York, NY: Springer.

Karau, S. J. & Willaims, K. D. (1993). Social loafing: A meta-analytic review and theoretical integration. *Journal of Personality and Social Psychology, 65*(4), 681-706.

Knorzer, L., Brunken, R. & Park, B. (2016). Emotions and multimedia learning: The moderating role of learner characteristics. *Journal of Computer Assisted Learning, 32*, 618-631. doi: 10.1111/jcal.12158.

Koszalka, T. A. & Wu, Y.Y. (2010). Instructional Design Issues in a distributed collaborative engineering design (CED) instructional environment. *Quarterly Review of Distance Education, 11*(2), 105-125.

Kumpulainen, K., & Kaartinen, S. (2003). The interpersonal dynamics of collaborative reasoning in peer interactive dyads. *Journal of Experimental Education*, *71*(4), 333-370.

Lee, C., Lin, Y., Huang, H., Huang, W., & Teng, H. (2015). The effects of task interdependence, team cooperation, and team conflict on job performance. *Social Behavior and Personality, 43*(4), 529-536.

Lewin, K. (1948). *Resolving social conflicts*. New York: Harper.

Lembke, S., & Wilson, M. G. (1998). Putting the 'team' into teamwork: Alternative theoretical contributions for contemporary management practice. *Human Relations, 51*(7), 927-944.

Lipset, S. M., Trow, M., & Coleman, J. (1956). *Union democracy: The inside politics of the International Typographical Union*. New York: Free Press.

Locke, E.A., Durham, C.C., Poon, J.M.L., & Weldon, E. (1997). Goal setting, planning, and performance on work tasks for individuals and groups. In S. L. Friedman & E. K. Scholnick (Eds.) *The developmental psychology of planning: Why, how, and when do we plan?* (pp. 239-262). Mahwah, NJ: Erlbaum.

Marks, M., Mathieu, J. E., & Zaccaro, S. J. (2001). A Temporally Based Framework and Taxonomy of Team Processes. *The Academy of Management Review*, *26*(3), 356-376.

McClintock, C. (1985). Process sampling: A method for case study research on administrative behavior. *Educational Administration Quarterly*, *21*, 205-222.

Meier, A., Spada, H., & Rummel, N. (2007). A rating scheme for assessing the quality of computer-supported collaboration processes. *Computer-supported Collaborative Learning, 2,* 63-86.

Mesch, D., Johnson, D. W., & Johnson, R. T. (1988). Impact of positive interdependence and academic group contingencies on achievement. *Journal of Social Psychology, 128*(3), 345-352.

Miller, L. & Hamblin, R. (1963). Interdependence, differential rewarding, and productivity. *American Sociological Review, 28,* 768-778. http://dx.doi.org/10.2307/2089914

Mitchell, T. R., & Silver, W. S. (1990). Individual and group goals when workers are interdependent: Effects on task strategies and performance. *Journal of Applied Psychology*, *75*, 185-193. http://dx.doi.org/10/1037/0021-9010.75.2.185

Patton, M. Q. (1999). Enhancing the Quality and Credibility of Qualitative Analysis. *Health Services Research, 34*(5), 1189-1208.

Pearsall, M. J., Christian, M. S., & Ellis A. P. J. (2010). Motivating interdependent teams: Individual rewards, shared rewards, or something in between? *Journal of Applied Psychology*, *95*(1), 183-191. http://dx.doi.org/10.1037/a0017593

Raven, B. H. & Shaw, J. I. (1970). Interdependence and group problem-solving in the triad. *Journal of Personality and Social Psychology, 14*(2), 157-165.

Rico, R. & Cohen, S. G. (2005). Effects of task interdependence and type of communication on performance in virtual teams. *Journal of Managerial Psychology, 20*, 261-274. http://dx.doi.org/10.1108/02683940510589046

Rico, R., Alcover, C. M., Sanchez-Manzanares, M., & Gil, F. (2009). The joint relationships of communication behaviors and task interdependence on trust building and change in virtual project teams. *Social Science Information, 48*(2), 229-255.

Roschelle, J., & Teasley, S. D. (1995). The construction of shared knowledge in collaborative problem solving. In C. E. O'Malley (Ed.), *Computer-supported collaborative learning* (pp. 69-197). Berlin, Germany: Springer.

Rourke, L., Anderson, T., Garrison, D.R., & Archer, W. (2001). Methodological issues in the content analysis of computer conference transcripts. *International Journal of Artificial Intelligence in Education, 12*(1), 8-22.

Rummel, N., Deiglmayr, A., Spada, H., Kahrimanis, G., & Avouris, N. (2011). Analyzing collaborative interactions across domains and settings: An adaptable rating scheme. In S. Puntambekar, G. Erkens, & C. Hmelo-Silver (Eds.), *Analyzing interactions in CSCL: Methods, approaches and issues* (pp. 368-390). New York, NY: Springer.

Salomon, G., & Globerson, T. (1989). When teams do not function the way they ought to. *International Journal of Educational Research, 13*(1), 89-99.

Schegloff, E.A., Jefferson, G., & Sachs, H. (1977). The preference for self-correction in the organization of repair in conversation. *Language, 53*, 361-382.

Schwaighofer, M., Vogel, F., Kollar, I., Ufer, S., Strohmaier, A., Terwedow, I., … & Fischer, F. (2017). How to combine collaboration scripts and heuristic worked examples to foster mathematical argumentation: When working memory matters. *International Journal of Computer-supported Collaborative Learning, 12*, 281-305. doi: 10.1007/s11412-017-9260-z.

Serce, F. C., Swigger, K., Alpaslan, F. N., Brazile, R., Dafoulas, G., & Lopez, V. (2011). Online collaboration: Collaborative behavior patterns and factors affecting globally distributed team performance. *Computers in Human Behavior, 27,* 490-503.

Shea, G. P. & Guzzo, R. A. (1987). Group effectiveness: What really matters? *Sloan Management Review*, *28*(3), 25-31.

Somech, A., Desivilya, H. S., & Lidogoster, H. (2009). Team conflict management and team effectiveness: The effects of task interdependence and team identification. *Journal of Organizational Behavior, 30*, 359-378. http://dx.doi.org/10.1002/job.537.

Stake, R. E. (1995). The Art of Case Study Research. Thousand Oaks, CA: Sage.

Thomson, A. I., Stone, A. L., & Ion, W. J. (2007). Distributed team design in small and medium sized enterprises - how to get it right. *AI EDAM - Artificial Intelligence for Engineering Design, Analysis and Manufacture*, *21*(3), 203-218.

Uribe, D., Klein, J. D., & Sullivan, H. (2003). The effect of computer-mediated collaborative learning on solving ill-defined problems. *Educational Technology Research and Development*, *51*(1), 5-19.

Van de Ven, A. H., Delbecq, A. L., & Koenig, R. (1976). Determinants of coordination modes within organizations. *American Sociological Review*, *41*, 322-338.

Van Der Vegt, G., Emans, B., & Van De VLiert, E. (1999). Effects of interdependencies in project teams. *Journal of Social Psychology*, *139 (2),* 202-214.

Van Der Vegt, G., Emans, B., & Van De Vliert, E. (2001). Patterns of interdependence in work teams: A two-level investigation of the relations with job and team satisfaction. *Personnel Psychology*, *54*, 51-69.

Wageman, R. (1995). Interdependence and group effectiveness. *Administrative Science Quarterly*, *40 (1),* 145-180. http://dx.doi.org/10.2307/2393703

Wageman, R. (1999b). Task design, outcome interdependence, and individual differences: Joint effects on effort in task-performing teams. *Group Dynamics*, *44*, 136-142.

Wageman, R. (2001). The meaning of interdependence, in M. E. Turner, (ed.) *Groups at Work: Theory and Research* (pp. 197-218). Mahwah, NJ: Erlbaum.

Wageman, R. & Baker, G. (1997). Incentives and cooperation: The joint effects of task and reward interdependence on group performance. *Journal of Organizational Behavior, 8*(2), 139-158. http://dx.doi.org/10.1002/(SICI)1099-1379(199703)18:2<139::AID-JOB791>3.0.CO;2-R

Wageman, R., Gardner, H., & Mortensen, M. (2012). The changing ecology of teams: New directions for teams research. *Journal of Organizational Behavior, 33,* 301-315. doi: 10.1002/job.1775

Wageman, R. & Gordon, F. M. (2005). As the twig is bent: How group values shape emergent task interdependence in groups. *Organization Science*, *16 (6),* 687-700.

Wagner, J. A. (1995). Studies of individualism-collectivism: Effects of cooperation in groups. *Academy of Management Journal, 38*(1), 152-172.

Woolley, A.W., Gerbasi, M.E., Chabris, C.F., & Kosslyn, S.M., & Hackman, J.R. (2008). Bringing in the experts: how team composition and collaborative planning jointly shape analytic effectiveness. *Small Group Research, 39*(3), 352-371.

Wu, Y.Y. & Koszalka, T.A. (2011). Exploring team technology use and collaborative communication in a dynamic distributed engineering educational environment. In Vincenti, G. & Braman, J. (Eds.) *Multi-user Virtual Environments for the Classroom: Practical Approaches to Teaching in Virtual Worlds*. Hershey, PA: IGI Global.

Yin, R. K. (2014). *Case study research: Design and methods* (5th ed.). Thousand Oaks, CA: Sage.

Yoshimura, M., & Takahashi, K. (2001). Collaborative design among different fields in mobile-agent environments. *International Journal of Concurrent Engineering: Research and Applications, 9*(2), 146–154.

Zeng, X. H. T, Duch, J., Sales-Pardo, M., Moreira, J. A. G., Radicchi, F., Ribeiro, H. V., Woodruff, T. K., & Amaral, L. A. N. (2016). Differences in Collaboration Patterns across Discipline, Career Stage, and Gender. *PLOS Biology*, *14*(11): e1002573. doi: 10.1371/journal.pbio.1002573.

Vita

Yiyan (Page) Wu

16580 Topping Way
Los Gatos, CA 95032
(315) 345-1263
ywu02@syr.edu

EDUCATION

Ph.D. candidate, Instructional Design, Development and Evaluation, Syracuse University, Syracuse, NY (expected Fall, 2017)
M.S., Applied Statistics, Syracuse University, Syracuse, NY (May, 2013)
M.S., Instructional Design, Development and Evaluation, Syracuse University, Syracuse, NY (August, 2005)
B.S., English Education, Jiangxi Normal University, Nanchang, China (July, 2000)

DISSERTATION

Behavioral Interdependence in Project Team Collaboration: Study of College Engineering Students' Collaborative Behaviors in High Levels of Interdependent Task Settings
Committee: Dr. Tiffany A. Koszalka (Chair), Dr. Nick L. Smith, Dr. Gerald S. Edmonds

FIELDS OF SPECIALIZATION

Primary: Instructional design
Secondary: Learning assessment and evaluation

PUBLICATIONS & REPORTS

Book Chapter
Wu, Y.Y. & Koszalka, T.A. (2011). Exploring team technology use and collaborative communication in a dynamic distributed engineering educational environment. In Vincenti, G. & Braman, J. (Eds.) *Multi-user Virtual Environments for the Classroom: Practical Approaches to Teaching in Virtual Worlds*. Hershey, PA: IGI Global.

Journal Article
Koszalka, T.A. & Wu, Y.Y. (2010). Instructional design issues in a distributed collaborative engineering design (CED) instructional environment. *Quarterly Review of Distance Education, 11(2),* 105-126.

Research (sponsored research) Reports
Koszalka, T. A. & Wu, Y.Y. (2007-2010). ESF NSF GK12 Mid-Year and final 2009-2010 Year Project Evaluation Reports. Submitted to *SUNY ESF, C. Spuches/ R. Beal*.

EDUCATIONAL RESEARCH / WORK EXPERIENCE

Office of Shared Accountability, Syracuse City School District
Data Analyst, June 2012 – December 2013

- Worked on multiple evaluation and analysis projects related to K-12 student performance and behaviors, teacher and school performance, early childhood learning, and community service and district partnerships
    - Led data analysis on student behaviors and learning outcomes by using statistical procedures such as ANOVA, regression, and multivariant regression
    - Collaborated on the district's annual teacher professional performance review (APPR) through the calculation of student and school growth scores by using the growth model
    - Collaborated on the evaluation of school-based educational initiatives and intervention programs including survey design, data analysis, and reporting
    - Collaborated on data sharing and analysis with regional, state, or national educational agencies on emerging issues including suspension, attendance, drop-out, college readiness, and racial inequity
- Collaborated on managing large quantities of data by using MS Access and Excel

Burton Blatt Institute, Syracuse University, Syracuse, NY
Research Assistant, Research and Evaluation Team, January 2009 – March 2012
The national program of *Entrepreneurship Bootcamp for Veterans with Disabilities* (EBV National), one of the most influential disability entrepreneur training programs nationwide

- Collaborated on the design and development of program evaluation interview protocols
- Collaborated on the analysis of a large amount of qualitative interview data by using QDAMiner
- Maintain effective communication with program trainees

College of Environmental Science and Forestry, State University of New York (SUNY), Syracuse, NY
Main Research Assistant, Program Evaluation Team, May 2008 – June 2010
The project of *Environmental Science and Forestry National Science Foundation GK-12 Educational Outreach*

- Collaborated on the design and implementation of evaluation instruments to collect student perception data
- Took the lead in data collection and analysis
- Assisted in writing evaluation reports

Department of Mechanical & Aerospace Engineering, Syracuse University, Syracuse, NY
Main Research Assistant, Course Evaluation Team, June 2006 – December 2007
The project of *Advanced Interactive Discovery Environment (AIDE) for Engineering Education*

- Research:
    - on the association between team communication and technology use in a virtual collaborative environment: independently designed the study instruments (survey & ranking scale), conducted case study design, and practiced data collection and analysis, and coauthored a book chapter addressing major factors influencing students' technology adoption and use patterns
    - on the association between student individual collaborative behaviors, team behavior changes, and team performance: as part of my dissertation study, I independently designed the research instruments; I used case study design and social network analysis to reveal student behavior changes and map out their interactive collaboration patterns
- Course evaluation: collaborated on the design and development of course evaluation instruments (survey & observation protocols), led data analysis, and coauthored a journal paper to address important course design issues including training of technology use, collaborative skills, and team and time management

Progressive Expert Consulting, Inc. Syracuse, NY
Research Intern, Research and Evaluation Team, September 2005 – February 2006
The project of *SOFTS* Language Training Program, a government-funded program which was designed to deliver foreign language training to geographically dispersed military soldiers by using virtual, collaborative educational technologies.

- Conducted virtual in-class observations
- Assisted in writing monthly course monitoring and project evaluation reports

Training Systems Institute, Department of Instructional Design, Development, and Evaluation, Syracuse University, NY
Research Assistant, Research and Evaluation Team, September 2003 – May 2004
The project of *PR*TEC* (*Pacific Regional Technology in Education Consortium*)

- Assisted in data management and analysis by using Excel
- Collaborated on compiling evaluation reports, including the writing of analysis results and addressing research findings related to the use of visual technology to enhance middle-school student science learning

UNIVERSITY TEACHING EXPERIENCE

Department of Instructional Design, Development, & Evaluation, Syracuse University, Syracuse, NY
Instructor, June 2007 – May 2008

- Delivered course lectures and assessed students' course work by providing grades and reflective feedback
- Educated graduate students and educational practitioners to use appropriate instructional strategies, assessment tools, and technologies to design good classroom instruction

CONFERENCE PRESENTATIONS

Referred Conference Presentations

Wu, Y.Y. (2018, October). Behavioral Interdependence in Project Team Collaboration. *Paper submitted at the Association for Educational Communication and Technology (AECT) Annual Conference*, Kansas City, Kansas.

Wu, Y.Y. (2015, April). Emergent Behavioral Interdependence in Project Team Problem-Solving. *Paper presented at the American Educational Research Association (AERA) Annual Conference*, Chicago, Illinois.

Wu, Y.Y. (2013, April). Team Collaboration in Distributed College Engineering Students' Problem Solving: Interdependence and Convergence. *Paper presented at the American Educational Research Association (AERA) Annual Conference*, San Francisco, California.

Wu, Y.Y. (2011, April). Exploring Team Communication and Technology Use in Virtual Collaborative Engineering Problem Solving. *Paper presented at the American Educational Research Association (AERA) Annual Conference,* New Orleans, Louisiana.

Wu, Y.Y. & Koszalka, T.A. (2010, October). Instructional design of a collaborative engineering design (CED) environment: exploring team technology use during virtual collaboration. *Paper presented at the Association for Educational Communication and Technology (AECT) Annual Conference,* Anaheim, California.

Koszalka, T.A., Eseryel, D., & Wu, Y.Y. (2008, October). Resuming the conversation: How should instructional designers be educated? *Paper presented at the Association for Educational Communication and Technology (AECT) Annual Conference,* Orlando, Florida.

Koszalka, T.A. & Wu, Y.Y. (2008, May). Evaluation of a cross-institutional collaborative distributed engineering educational environment. *Paper presented at the 12th Global Chinese Conference on Computers in Education Conference (GCCCE),* Lansing, Michigan (**Excellent Paper Award**).

Wu, Y.Y. & Wu, C.P. (2006, November). The potential and problems of webcam data collection in evaluating web-conference learning. *Paper presented at the American Evaluation Association (AEA) Annual Conference,* Portland, Oregon.

Wu, Y.Y. (2006, March). Cost-benefit analysis for program evaluation in not-for-profit, professional organizations. *Paper presented at the Twentieth Annual Edward F. Kelly Conference*, Albany, New York.

Other Professional Presentations

Gonzalez, J., Wu, C.P., & Wu, Y.Y. (Oct 2007). Evaluating teacher knowledge in technology-integrated instruction – TPCK. Graduate seminar presentation to visiting teachers and administrators from Thailand, Syracuse, NY.

AWARDS & GRANTS

- AECT/NSF Early Career Faculty Symposium Grant *October 2011*
- Burton Blatt Graduate Scholarship *August 2010*
- PSLC (Pittsburg Science Learning Center) Summer School Fellowship *July, 2009*
- School of Education Research & Creative Grant *May 2009*
- William L. Millard Instructional Technology Graduate Scholarship *Sept. 2005*
- Syracuse University Graduate Scholarship *2003-2009*

SERVICE TO THE PROFESSION

Proposal Reviews

- Association of Educational Communication & Technology (AECT) 2018 Annual Conference – Division of Research and Theory TIG
- American Evaluation Association (AEA) 2009 & 2010 Annual Conferences - Qualitative Methods TIG
- American Evaluation Association (AEA) 2010 Annual Conference - Research, Technology, and Development Evaluation TIG
- American Evaluation Association (AEA) 2009 Annual Conference - Distance Education & Other Educational Technologies TIG
- Association of Educational Communication & Technology (AECT) 2008 Annual Conference - Division of Design & Development: mentored by Dr. Tiffany A. Koszalka
- Association of Educational Communication & Technology (AECT) 2008 Annual Conference - International Division: mentored by Dr. Ross A. Perkins
- The 12th Global Chinese Conference on Computers in Education Conference (GCCCE) 2008
- The 11th Global Chinese Conference on Computers in Education Conference (GCCCE) 2007

Conference Participation as Moderator

- American Evaluation Association Annual Conference 2009
- Association of Educational Communication & Technology Annual Conference 2008
- E-Learn 2007: World Conference on E-Learning in Corporate, Government, Healthcare & Higher Education

Conference Evaluation

- Graduate Student Volunteer Program, Association of Educational Communication & Technology (AECT) Annual Conference 2006
    - Collaborated on conference internal evaluation, including assisted in drafting the evaluation plan, identified cost-analysis as the main tool, and collaborated on conducting on-site observations

PROFESSIONAL MEMBERSHIPS

- Association for Educational Communications and Technology
- American Evaluation Association
- American Educational Research Association